Focused-Source Electromagnetic (FSEM) Method: A New Technology to Improve Resolution of the Conventional CSEM

Dr. Sofia Davydycheva, 3DEM Consulting (Houston, Texas), Email: sdavyd@gmail.com
Dr. Nikolai Rykhlinski, Inst. of Innovative Geophysics (Moscow), Email: rykhlinski@mail.ru

About 3DEM Consulting Company

3DEM Consulting offers a wide spectrum of modeling services for any borehole, onshore, and offshore geophysical electromagnetic acquisition systems. The state-of-the-art proprietary 3DEM software provides unique capabilities to accurately model arbitrary 3D resistivity structures. It can efficiently handle dipping anisotropy, seabed bathymetry, faults, waterfronts, etc. To best of our knowledge, there is no other EM company that can offer 3DEM software of a similar high level of sophistication and efficiency.

3DEM Consulting has developed and has full access to a novel onshore/offshore EM acquisition technology enabling more reliable exploration and accurate delineation of deep hydrocarbon reservoirs. This technology has been successfully tested on numerous case studies. 3DEM Consulting has been awarded several patents in Russia; international patents are pending.

Summary

Controlled-Source Electromagnetic (CSEM) measurements are sensitive to the physical properties of rocks and fluids such as oil, gas, and water through their electrical conductivity. Because of low spatial resolution the effective use of CSEM can only be achieved via integration with seismic and application of rigorous and time-consuming 3D inversion-based interpretation. We suggest a principal improvement of the conventional CSEM method having significantly higher spatial resolution: a new Focused-Source Electromagnetic (FSEM) technology exploiting the idea of vertical focusing of the EM field. The idea of FSEM came from the resistivity well logging, which has come a long way from the first primitive logging devices, giving only an approximate estimate of the formation resistivity in shallow zone around the borehole, to modern accurate focusing tools like Laterolog.

Marine or land EM is a relatively new technique, however, FSEM has already proven its efficiency in different oil provinces (e.g., Russia and other republics of the FSU) where the conventional CSEM has restricted applicability due to strong magnetotelluric noise and complex geological environments (shallow resistive gas-hydrates, rock salt, basalt intrusions, etc.). High spatial resolution of FSEM allows interpreting EM data using fast 1D inversion even in complicated 3D formations, while the conventional CSEM requires application of full-blown 3D inversion techniques. We believe that the novel FSEM technology will quickly become a reliable addition to seismic.

FSEM sensors for offshore and onshore applications

3DEM Consulting has developed and successfully tested in different field environments prototypes of the following tools:

- Grounded electric dipole and quadrupole transmitters and receivers for onshore applications.
- Towed marine transmitters and receivers.

Note: development of our stationary sea-bottom receivers is ongoing.

FSEM 3D modeling and interpretation tools

- 3DEM Consulting offers a powerful and universal software package to model complex EM data acquisition schemes over arbitrary anisotropic media.
- Fast inversion-based EM interpretation software is being developed.

Benchmark Modeling and Field Examples

Results of 3D modeling of the conventional CSEM and novel FSEM method are shown in Figs. 1-2. Fig. 3 shows results of a recent successful field test in Eastern Siberia. Two HC reservoirs were opened in sandstones under ~2 km of carbonate and permafrost overburden. In addition to the formation resistivity imaging, we obtained images of the Induced Polarization (IP) parameter, which led to a more reliable resistivity interpretation.

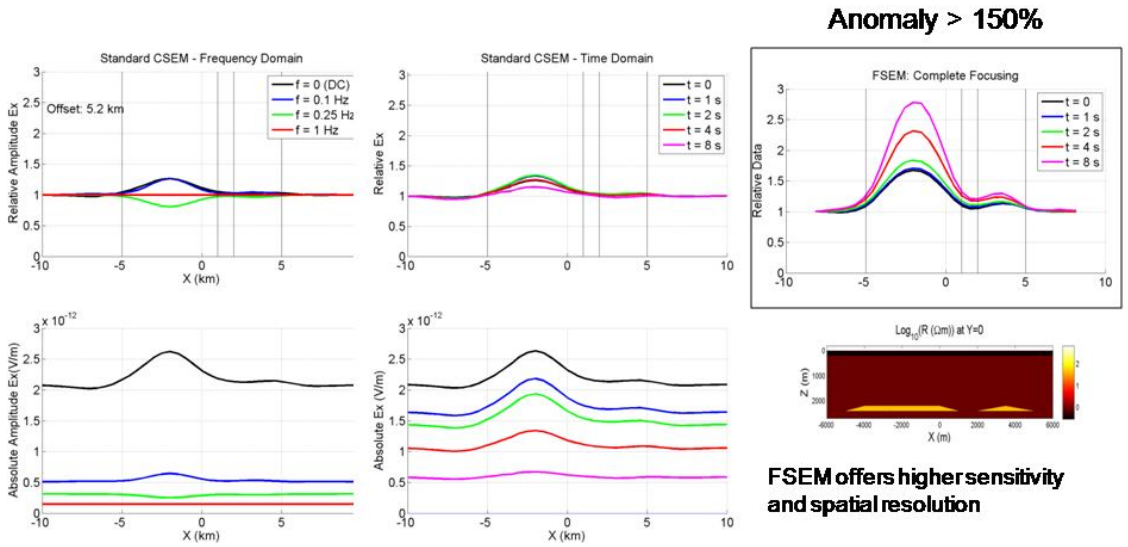


Fig. 1: Synthetic responces from two HC reservoirs located 2 km below the mudline: frequency-domain CSEM (a), time-domain CSEM (b), and time-domain FSEM (c). This shallow water example (water depth is 200 m) demonstrates higher resolution and depth of investigation of FSEM than conventional CSEM.

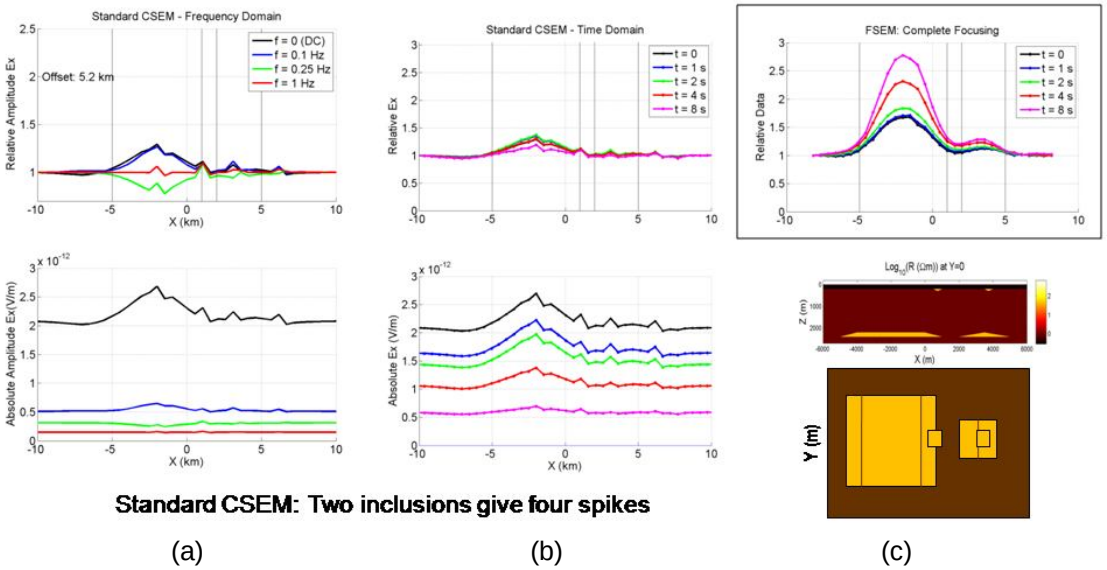
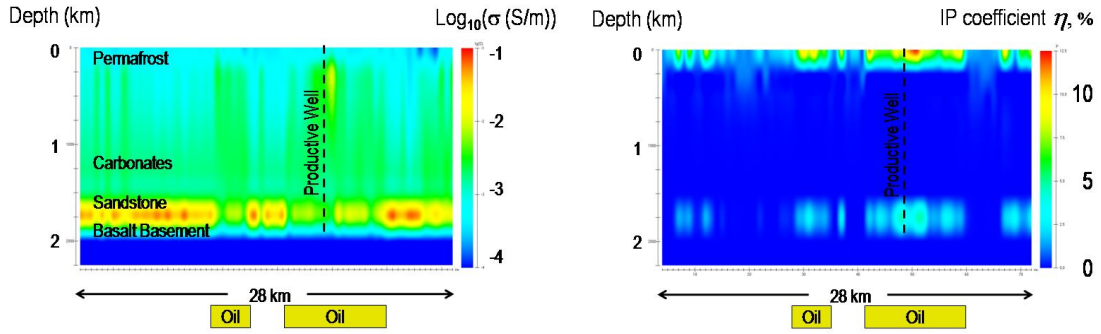


Fig. 2: Synthetic responces from two HC reservoirs located 2 km below the mudline (water depth 200 m) and two shallow resistive inclusions adjacent to the seafloor: frequency-domain CSEM (a), time-domain CSEM (b), and time-domain FSEM (c). This example (after Davydycheva and Rykhlinski, SEG 2009) demonstrates ability of the FSEM technology to remove shallow effects.



(a) (b)

Fig. 3: Case Study (Tympuchikan, Eastern Siberia, gas-condensate field): 1D inversion results for the electric conductivity (a) and the IP coefficient η (b).

Proposals

To initiate testing and further development of the FSEM technology, we would like to propose the following scope of work:

- Perform field trials of the FSEM technology.
- Develop next generation of FSEM source and receiver equipment.
- Develop new specialized fast 3D modeling and 1D inversion modules for FSEM applications.
- Provide consulting services: R&D projects, complex modeling and EM data interpretation jobs.

A core team of 2-3 world-class scientists and engineers will be built to manage short (12 mo) and longer-term (24+ mo) projects.

Client will have preferred access to the advanced technologies developed by 3DEM Consulting.

A detailed scope of work, deliverables, budget, and schedule will be provided.

Selected References

Our team has published a large number of scientific papers in the most prestigious journals and holds a number of patents. Our work has been highly appreciated by the geophysical community. In fact, we received best paper awards from The Log Analyst (1999) and Geophysics (2003).

- Davydycheva, S., Druskin, V., and Habashy, T., 2003, An efficient finite-difference scheme for electromagnetic logging in 3D anisotropic inhomogeneous media: Geophysics, 68 (5), 1525-1536 (***2003 Honorable mention in category of best papers in Geophysics***).

- Davydycheva, S., Rykhlinski, N., and Legeido, P., 2006, Electrical-prospecting method for hydrocarbon search using the induced polarization effect: Geophysics, 71, G179-G189.

- Davydycheva, S., and Rykhlinski, N., 2009, Focused Source EM Survey versus time- and frequency-domain CSEM: The Leading Edge, 28 (8), 944-949.