

# Oil & Natural Gas Technology

DOE Award No.: DE-FE0024271

## Fracture Diagnostics Using Low Frequency Electromagnetic Induction and Electrically Conductive Proppants

Submitted by:

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Quarterly Progress Report

*M. M. Sharma*

Mukul M. Sharma

Oct. 15, 2016

Date



Office of Fossil Energy



## **2. ACCOMPLISHMENTS:**

- The new subcontract with E-Spectrum Technologies was finalized and signed.
- We have organized biweekly meetings with E-Spectrum Technologies to ensure that there is good coordination between the two teams.
- 6 such half-day meetings were held with the E-Spectrum team.
- Simulations were conducted to simulate the shallow earth test site. These simulations indicated that such a test would provide measureable signals and valuable data.
- The importance of incorporating bucking coils in the tool design was demonstrated by the simulations.
- The impact of the transmitter and receiver coil lengths was also demonstrated. It was decided that the coil length would be 30 cm while that of the receiver coils would be 5 to 10 cm.
- Specifications for the tool design and the testing conditions were finalized based on simulations conducted.
- The transmitter and receiver spacing for the shallow earth test will be 0.5, 1.0 and 1.5m.
- Based on these design specifications a new design for the transmitter coil was finalized. This transmitter is now under fabrication.
- A suitable design of the test site was prepared.
- Resistivity measurements were made of the soil at the test site. There is some concern that the soil is very resistive.
- We expect that we will meet the milestone to have to have the prototype tool built by the end of the year.

## **3. PRODUCTS:**

None.

## **4. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS:**

Name:	Yaniv Brick
Project Role:	Postdoctoral Fellow
Nearest person month worked:	3
Contribution to Project:	Need Info
Funding Support:	ICES Postdoctoral Fellowship
Collaborated with individual in foreign country:	No
Country (ies) of foreign collaborator:	No
Travelled to foreign country:	No
If traveled to foreign country (ies), duration of stay:	0 months

## **Partner Organizations**

Organization Name: E-Spectrum Technologies.

Location of Organization: San Antonio, Texas

Partner's contribution to the project:

- Collaborative research (e.g., partner's staff work with project staff on the project).
- Design and building of tool.

More detail on partner and contribution:

- Three joint meetings were held with E-Spectrum to better define the tool requirements and the results needed from the simulations to help with the tool design.

## **5. IMPACT:**

The proposed technology has the following key advantages, which is not presently offered by any technology in the market:

- a. It can be executed from a single wellbore.
- b. It is a direct far field measurement.
- c. This tool can be run in hole after hydraulic fracturing. If the need arises, it can be used at any time during the well's life cycle providing a time lapse analysis of fracture growth or closure.
- d. Since it obtains tri-directional signals, these tensors can be resolved to obtain a simulated volume map, which can be correlated directly to the productivity of a given well.
- e. This is the only technology that can obtain propped fracture length, which governs productivity of a given well. Also it can be used to detect proppant banking or anisotropy in hydraulic fracture growth.

We anticipate that the technology will have a very significant impact on fracture diagnostics as it is cheap, repeatable, and fairly simple to run. In addition to the key critical advantages mentioned above the proposed technology can also offer the following benefits which are in line with DOE's ongoing efforts:

- a. **Additional recovery:** This tool can improve our understanding of true stimulated rock volume, since it tracks propped volume of hydraulic fractures and not shear slip events during a fracturing job. Therefore, using this technology, we can model the reservoir better and find effective re-fracturing candidates. Also a true stimulated rock volume map can help us design better simulations for subsequent wells.
- b. **Reduced costs:** This tool can be operated at any time during the well's life cycle and not necessarily during the hydraulic fracturing job ( as is the case with microseismic monitoring). Therefore, it will be reduce the equipment load during a fracturing job, thereby reducing the environmental footprint. Since this technology, being a single wellbore application, doesn't require a monitoring well, it can be potentially deployed in any hydraulically fractured well with or without a rig (can be deployed with a MAST truck too). Due to the simplicity of deployment and ease of operation, we

anticipate a much reduced cost as compared to microseismic monitoring while providing more reliable results.

- c. Environmental benefits: This technology basically tracks the location of conductive proppant using the proposed electromagnetic logging tool. Therefore it can be used to track if the fractures are hydraulically connected to natural aquifers. This tool can be run alongside Cement Bond Logs, in fractured reservoirs to ensure hydraulic isolation of oil and gas producing zones. Also the inverted product of this data can be combined with other geophysical data (2D and 3D seismic and/or CSEM data) to find connection with natural fractures.

**6. CHANGES/PROBLEMS:**

None.

**7. SPECIAL REPORTING REQUIREMENTS:**

None.

**8. BUDGETARY INFORMATION:**

**EXHIBIT 1 – MILESTONE STATUS REPORT**

Milestone Title/Description	Planned Completion Date	Actual Completion Date	Verification Method	Comments (Progress toward achieving milestone, explanation of deviation from plan etc.)
Task 1. Project Management & Planning				
Milestones				
Completed project management & planning	11/1/14		PMP document	
Task 2. Development of forward model using proposed tool and different fracture geometries				
Milestones				
model of fracture in well completed	6/30/15			
forward model to observe signal	9/30/15			
important operational parameters	3/31/16			
Publication #1			Paper publication submitted	
Task 3. Lab testing of available proppants in the market for electrical and material properties				
Milestones				
identify the best proppants for their electrical conductivity and strength	3/31/16		Lab test report provided for review	
Task 4. Construction of low frequency electromagnetic tool				
Milestones				
low frequency electromagnetic tool built and lab tested according to well specifications	12/31/16			
Task 5. field testing of tool				
Milestones				
Built tool deployed in well	2/28/17		Tool is deployed on well site	
publication #2			Paper publication submitted	
Task 6. Inverting the obtained field data for stimulated rock volume (SRV) map				
Milestones				
invert the tool signal to obtain stimulated rock volume (SRV) map				
Publication #3	10/31/17		Paper publication submitted	
illustrate the new technology as a fracture diagnostic tool				
Final Report	12/31/17		Final report	

**EXHIBIT 2- COST PLAN**

Baseline Reporting Quarter	Budget Period 1								Budget Period 2								Budget Period 3							
	Q1		Q2		Q3		Q4		Q1		Q2		Q3		Q4		Q1		Q2		Q3		Q4	
	10/1/14-12/31/14	Cumulative Total	1/1/15-3/31/15	Cumulative Total	4/1/15-6/30/15	Cumulative Total	7/1/15-9/30/15	Cumulative Total	10/1/15-12/31/15	Cumulative Total	1/1/16-3/31/16	Cumulative Total	4/1/16-6/30/16	Cumulative Total	7/1/16-9/30/16	Cumulative Total	10/1/16-12/31/16	Cumulative Total	1/1/17-3/31/17	Cumulative Total	4/1/17-6/30/17	Cumulative Total	7/1/17-9/30/17	Cumulative Total
<b>Baseline Cost Plan</b>																								
Federal Share	\$ 133,921	\$ 133,921	\$ 267,843	\$ 401,764	\$ 133,921	\$ 535,685	\$ 133,921	\$ 669,607	\$ 133,921	\$ 803,529	\$ 133,921	\$ 937,451	\$ 133,921	\$ 1,071,372	\$ 133,921	\$ 1,205,293	\$ 133,921	\$ 1,339,215	\$ 1,473,137	\$ 1,607,058	\$ 1,740,979	\$ 1,874,900	\$ 2,008,821	\$ 2,142,742
Non-Federal Share	\$ 48,602	\$ 48,602	\$ 97,205	\$ 145,807	\$ 48,602	\$ 194,409	\$ 48,602	\$ 243,011	\$ 48,602	\$ 291,614	\$ 48,602	\$ 340,216	\$ 48,602	\$ 388,818	\$ 48,602	\$ 437,420	\$ 48,602	\$ 486,023	\$ 534,625	\$ 583,228	\$ 631,830	\$ 680,432	\$ 729,034	\$ 777,636
Total Planned	\$ 182,523	\$ 182,523	\$ 365,048	\$ 547,571	\$ 182,523	\$ 730,094	\$ 182,523	\$ 912,618	\$ 182,523	\$ 1,095,143	\$ 182,523	\$ 1,277,667	\$ 182,523	\$ 1,460,190	\$ 182,523	\$ 1,642,713	\$ 182,523	\$ 1,825,238	\$ 1,997,762	\$ 2,190,286	\$ 2,371,812	\$ 2,555,332	\$ 2,739,852	\$ 2,924,372
<b>Actual Incurred Cost</b>																								
Federal Share	\$ 30,972	\$ 30,972	\$ 26,895	\$ 57,858	\$ 99,655	\$ 157,613	\$ 148,601	\$ 419,299	\$ 113,085	\$ 56,524	\$ 475,823	\$ 531,112	\$ 85,464	\$ 616,576	\$ 616,576	\$ 616,576	\$ 616,576	\$ 616,576	\$ 616,576	\$ 616,576	\$ 616,576	\$ 616,576	\$ 616,576	\$ 616,576
Non-Federal Share	\$ 75,222	\$ 75,222	\$ 64,495	\$ 139,717	\$ -	\$ 139,717	\$ -	\$ 166,227	\$ 26,510	\$ 192,737	\$ 78,190	\$ 270,928	\$ 34,669	\$ 305,596	\$ 305,596	\$ 305,596	\$ 305,596	\$ 305,596	\$ 305,596	\$ 305,596	\$ 305,596	\$ 305,596	\$ 305,596	\$ 305,596
Total Incurred Costs	\$ 106,194	\$ 106,194	\$ 91,400	\$ 197,575	\$ 99,655	\$ 297,330	\$ 148,601	\$ 585,526	\$ 139,595	\$ 83,034	\$ 668,560	\$ 813,400	\$ 120,132	\$ 922,172	\$ 922,172	\$ 922,172	\$ 922,172	\$ 922,172	\$ 922,172	\$ 922,172	\$ 922,172	\$ 922,172	\$ 922,172	\$ 922,172
<b>Variance</b>																								
Federal Share	\$ 102,949	\$ 102,949	\$ 106,897	\$ 244,151	\$ 34,866	\$ 229,471	\$ -14,800	\$ 250,308	\$ 20,837	\$ 71,398	\$ 327,706	\$ 406,338	\$ 48,457	\$ 454,796	\$ 48,457	\$ 588,717	\$ 133,921	\$ 724,639	\$ 1,049,215	\$ 1,365,791	\$ 1,682,367	\$ 1,998,943	\$ 2,315,519	\$ 2,632,095
Non-Federal Share	\$ -26,620	\$ -26,620	\$ -45,892	\$ -6,090	\$ 48,602	\$ 54,692	\$ 48,602	\$ 76,794	\$ 22,092	\$ 22,092	\$ 98,877	\$ 29,589	\$ 69,288	\$ 13,933	\$ 83,222	\$ 48,602	\$ 131,824	\$ 48,602	\$ 180,427	\$ 269,029	\$ 358,031	\$ 447,033	\$ 536,035	\$ 625,037
Total Variance	\$ 76,329	\$ 76,329	\$ 162,789	\$ 250,241	\$ 83,468	\$ 284,163	\$ 33,922	\$ 327,092	\$ 42,929	\$ 99,491	\$ 426,583	\$ 475,627	\$ 475,627	\$ 568,729	\$ 536,914	\$ 667,323	\$ 825,523	\$ 993,066	\$ 1,164,525	\$ 1,365,791	\$ 1,555,332	\$ 1,743,852	\$ 1,933,852	\$ 2,127,114