SensorEra

Induced seismicity in Howard County II:

Comparing Rapid Deployment of New Microelectromechanical Systems (MEMS) Seismic Stations vs. Traditional Seismometers for Detection of Near Field and Far Field Earthquakes

Nicholas J. Brooks[1], Tianrun Chen[1], Xinding Fang[1], Alan R. Huffman[2], Tony Lupo[3], Rachel Storniolo[4]

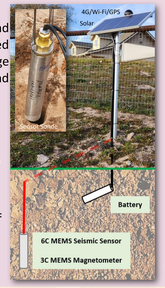
(1. SensorEra Inc; 2. HighPeak Energy Inc.; 3. SM Energy; 4. Birch Resources)

1.Objectives/Scope

We have developed an autonomous, low-cost and real-time sensor network system for monitoring induced seismicity. To evaluate the system's performance compared to conventional broadband seismometers, we conducted a field experiment in Howard County, Texas from mid-August to the end of October 2022. The experiment involved the installation of four new sensors, with one co-located with the TexNet MB12 station, two placed near privately-operated local seismometers and the fourth being a standalone unit.

Low-Cost Seismic Stations

The autonomous stations are micro-chip based and measure 6C ground motion. Full autonomy is provided by battery, solar, 4G, Wi-Fi and GPS. On board storage provides redundancy. Equipment is small and light and can be installed within 1 hour.



6C Sensor Specifications

Bandwidth: DC-4kHz | **Sample Rate:** 100-2000Hz

Measurement range: ±2g (A) ±15°/s (G)

Self-noise (A): Generation I: 8ug/√Hz (obsolete) , Generation II: 1.0ug/√Hz (current)

Self-noise (G): 5urad/√Hz

Timing: GNSS (GPS, GLONASS, GALILEO) | **Sensor clock accuracy:** <0.5ms

Transmission: 4G/Wi-Fi/Starlink

Onboard O.S.: Embedded Linux | **Cloud control & storage:** AWS | **Onboard Storage:** 32GB

Orientation: 3C magnetometer

Power Consumption: 4W

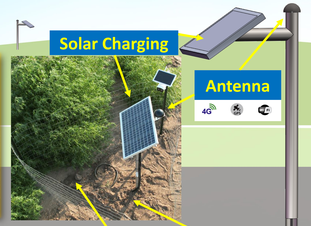
2. Methods

TexNet is a seismic monitoring program that operates with the Center for Injection and Seismicity Research under the Bureau of Economic Geology, UT, using public funding from the State of Texas and sponsorship from private operators. The program has 300+ active seismic stations, which vary in type but are typically broadband traditional force balance seismometers. Our field study compares these expensive seismometers with new low-cost, chip-based sensor technology and suitability for induced seismic monitoring, rapid deployment, and lower cost densification the existing network.

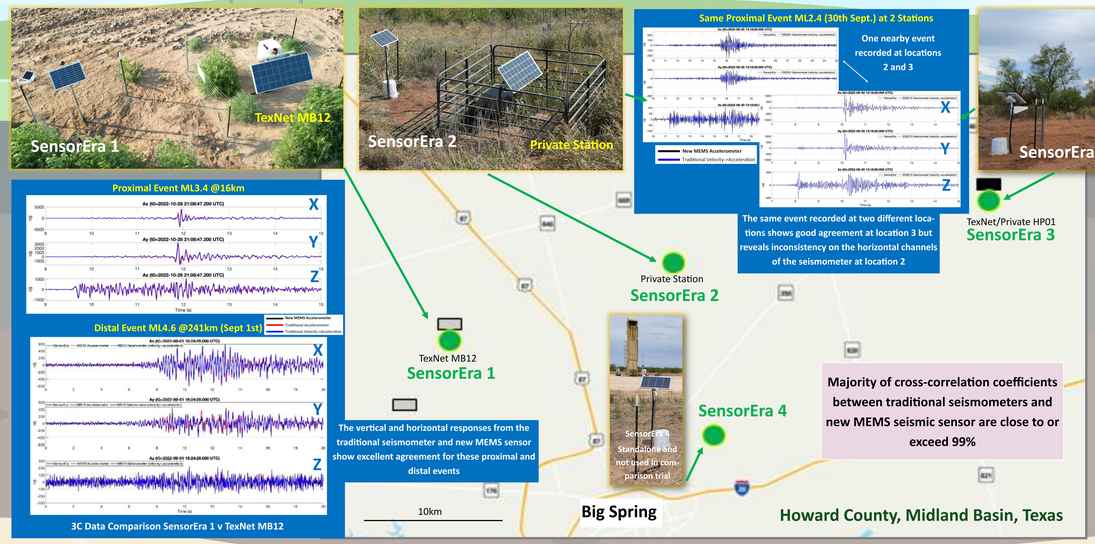
We show that modern MEMS accelerometers can now be used as seismicity sensors due to improved self-noise-floor and ability to record strong events in close proximity as well as monitor distant teleseismic earthquakes at very low frequencies. The technology meets the ideal requirements of a flat response over a broad range of frequencies and sensitivity over a wide dynamic range.

The vertical and horizontal responses from the traditional seismometer and new MEMS sensor show excellent agreement for these proximal and distal events

The same event recorded at two different locations shows good agreement at location 3 but reveals inconsistency on the horizontal channels of the seismometer at location 2

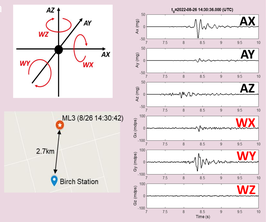


Low-Cost SaaS Chip–Based Seismic Station "SeismicityAlert"



Majority of cross-correlation coefficients between traditional seismometers and new MEMS seismic sensor are close to or exceed 99%

Six-Component (6C) Sensing



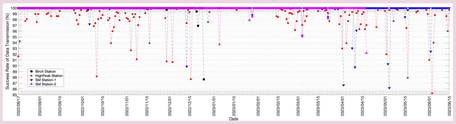
The sensors measure translational motion and 3-component rotation. When there is strong motion, such as a 2.7km ML 3 quake, the response can be seen on all six components.

3. Results, Observations, Conclusions

The sensors recorded six proximal events and two distal events and were consistent with three benchmarking seismometers in terms of both absolute seismic amplitude and phase. The sensor's frequency response was consistent with that of a broadband seismometer down to 0.03Hz and its self-noise was sufficient to achieve a magnitude of completeness down to 0ML within a 10km distance. The sensors are self-oriented and stabilize immediately after deployment, making them ideal for rapid short-notice deployment.

The reprocessing study using a densified array and local high-resolution velocity model shows the event depths to be shallower than previously estimated by TexNet. This reduced the magnitude values and may have implications for operators and the concerns of the general public.

System Reliability



All stations maintained >98% average success rate of real-time data transmission with ~600MB/day over the duration of the field trial.

4. Significance/Novelty

A new low-cost sensor system has been developed that allows improved reporting of hypocenter locations compared to sparser regional arrays. The system enables rapid deployment of denser arrays at a reduced cost, and its seismic response is comparable to traditional seismometer technology even at very low frequencies. The reprocessing study shows the importance of near offset dense arrays and high-resolution local velocity models.

Acknowledgements

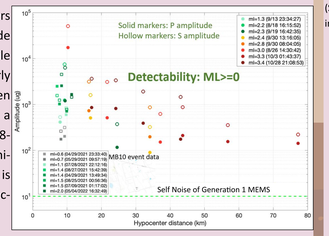
We thank our co-authors at HighPeak Energy, SM Energy and Birch Resources as well as ESG for providing the data from the private array.

Magnitude of Completeness

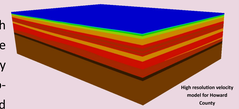
Event ID	Origin time (UTC)	ML
texnet2022qdqk	8/18 16:15:52	2.2
texnet2022qscz	8/26 14:30:42	3.0
texnet2022skdj	9/19 16:42:35	2.3
texnet2022tdou	9/30 08:04:05	2.8
texnet2022tdzc	9/30 13:16:05	2.4
texnet2022tiot	10/3 01:43:37	3.3
texnet2022vdsu	10/28 21:08:53	3.4
ESG local event	9/13 23:34:27	1.31

The trial recorded eight seismic events, seven being detected by TexNet and the new sensors and one from a private network. The data was analyzed based on distance from the hypocenter and the amplitude in µg. The plot shows the P and S amplitudes of each event as recorded by the new sensors, with weaker events registered by TexNet around their MB10 station represented as squares. The legend in the top right shows the colors representing each event.

The traditional seismometers show a minimum amplitude of approximately 100µg, while stronger events seen nearly 80km away show ML between 3-4. The new sensors, with a self-noise amplitude of 8-10µg, are suitable for monitoring in this area as this is well below the smallest recorded signal amplitude.



Reprocessing TexNet Events Using Private Network



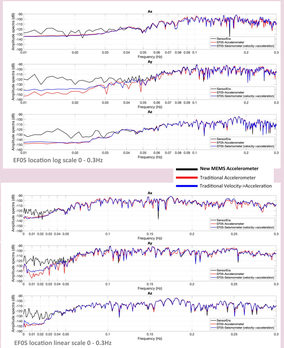
Three operators have a private network of 14 sensors, which were installed and operated by a third party. Six events were recorded by the private network that were also registered by the TexNet seismometers and new sensors. One operator provided a 3D velocity volume through the area, and we processed the events using a unique proprietary automated processing workflow in the cloud and compared results with TexNet processing, using the new velocity model.

Reprocessed data shows a reduction in depth to event (hypocenter) by 4.0-8.15km, resulting in a reduction in local magnitude of each event. The epicenter difference error ranges from 0.95-3.48km.

(See: IMAGE 2023 IPS 2 "Induced seismicity in Howard County IV: Numerical investigation of wave propagation in a complex layered sedimentary basin velocity field and the impact on travel paths and event locations")

TexNet Results			New Results			Difference	
Event	Depth	Local Magnitude	Depth	Local Magnitude (TexNet model)	Local Magnitude (SensorEra model)	Epicenter Difference	Depth Difference
ML2.2 8/18	7.7 km	2.2	3.25 km	2.09	1.99	1.85 km	-4.45 km
ML3.1 8/26	12.2 km	3.1	4.05 km	3.04	2.97	0.81 km	-8.15 km
ML2.3 9/19	8.1 km	2.3	4.1 km	2.18	2.08	1.88 km	-4 km
ML3.4 10/28	8.4 km	3.4	4.3 km	3.28	3.24	0.95 km	-4.1 km
ML 2.8 9/30	8.6 km	2.8	2.75 km	2.63	2.60	2.95 km	-5.85 km
ML2.4 9/30	10.7 km	2.4	2.75 km	2.21	2.18	2.03 km	-7.95 km

Low Frequency Response— Mexico Teleseismic Earthquake M7.6



A M7.6 earthquake occurred over 1000km from the sensors in Texas, which was detected by TexNet and the new stations. The data demonstrated a 99% cross-correlation coefficient between the seismometer and the MEMS device with excellent correlation down to 0.03Hz.

Induced seismicity in Howard County, TX

A Five Part Series at IMAGE 2023:

Part I – "Induced seismicity in Howard County I: The Buried Grenville Front in the Midland Basin and its Role in Localizing Induced Seismicity, Texas." IPS 2: Induced Seismicity in Midland, Texas (SM Energy)

Part II - "Induced seismicity in Howard County II: Comparing rapid deployment of new microelectromechanical systems (MEMS) seismic stations vs. traditional seismometers for detection of near field and far field earthquakes" (this poster)

Part III – "Induced seismicity in Howard County III: Event Relocation Using Local High Resolution Velocity Models and The Impact on Event Locations and Magnitudes." IMAGE 2023 IPS P2: Observation (ESG)

Part IV – "Induced seismicity in Howard County IV: Numerical investigation of wave propagation in a complex layered sedimentary basin velocity field and the impact on travel paths and event locations" IPS 2: Induced Seismicity in Midland, Texas (SensorEra)

Part V - "Induced seismicity in Howard County V: Technical and regulatory challenges for induced seismicity and deep disposal of fluids" IPS 2: Induced Seismicity in Midland, Texas (HighPeak Energy)