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

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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.

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 of new and existing networks such as TexNet.

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. We establish that the technology meets the ideal requirements of a flat response over a broad range of frequencies and sensitivity over a wide dynamic range.

3. Results, Observations, Conclusions

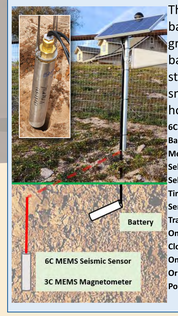
The sensors recorded six proximal events and two distal events and were consistent with three benchmarking seismometers in terms of both absolute seismic amplitude and phase. The sensor's frequency response was consistent with that of a broad-band seismometer down to 0.03Hz and its self-noise was sufficient 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 study compares 3C trace data across multiple events reported by USGS/TexNet. The comparison was conducted across all collocated MEMS-Seismometer stations, ranging from 16km to 1,320km distance from the epicenter. The results showed consistency in both time-amplitude and frequency-amplitude comparisons, with high cross-correlation coefficients across all ranges and frequencies.

4. Significance/Novelty

A new fully-autonomous solar-powered and low-cost sensor system has been developed that allows for improved reporting of earthquake hypocenter locations compared to sparser regional seismometer arrays. The system enables rapid deployment of dense arrays at a reduced cost, and we demonstrate that its seismic response is comparable to traditional seismometer technology even at very low frequencies. The Magnitude of Completeness shows detectability down to ML0 at 10km distance.

Objectives/Scope: Low-Cost Seismic Stations

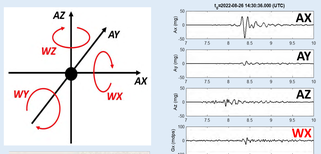


The autonomous stations are micro-chip based and measure six-component (6C) ground motion. Full autonomy is provided by battery, solar, 4G, Wi-Fi and GPS. Onboard storage provides redundancy. Equipment is small and light and can be installed within 1 hour.

6C Sensor Specifications

Bandwidth: DC-4kHz | **Sample Rate:** 100-2000Hz
Measurement range: ±2g (A) ±15°/s (G)
Self-noise (A): Gen I: 8ug/√Hz (obsolete) , Gen 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

Objectives/Scope: Six-Component (6C) Sensing



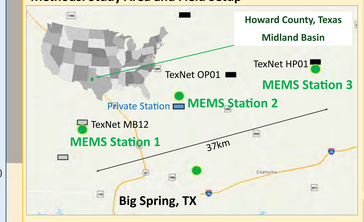
The sensors measure 3-component translational motion and 3-component rotation. When there is strong motion, such as a 2.7km ML 3 quake close by, the response can be seen on all six components.

Lithium Battery

6C Motion Sensor
3C Magnetometer

SensorEra

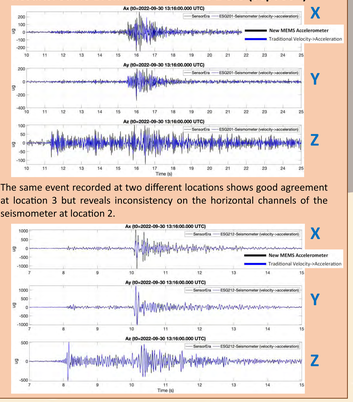
Methods: Study Area and Field Setup



Methods: Rapid Deployment and Retrieval

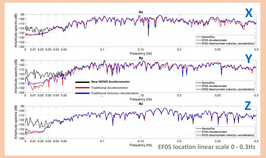
Sensor stations can be easily transported by road, with up to tens of stations per vehicle. On-site installation involves making a 3-4ft hole for the sensors and setting up charging and communications masts using only handheld equipment. Installation time including cattle fence is 1-2 hours and removal time is 1 hour. The new MEMS sensors are self-oriented by on-board magnetometer and require no settling time to begin recording immediately.

Results: Same Event ML2.4 Stations 2 & 3 (Sept 30th)

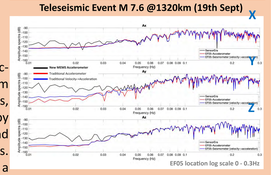


The same event recorded at two different locations shows good agreement at location 3 but reveals inconsistency on the horizontal channels of the seismometer at location 2.

Results: Low Frequency Response



Teleseismic Event M 7.6 @1320km (19th Sept)

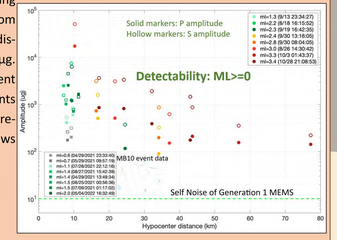


A M7.6 earthquake occurred over 1000km from the sensors in Texas, which was detected by TexNet seismometers and the new MEMS stations. The data demonstrated a 99% cross-correlation coefficient between the seismometer and the MEMS device with excellent correlation down to very low frequencies (0.03Hz).

Results: Magnitude of Completeness

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.

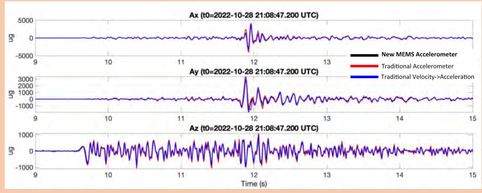
Event ID	Origin time (UTC)	ML
texnet2022qdqk	8/18 16:15:52	2.2
texnet2022qscz	8/26 14:30:42	3.0
texnet2022skdj	9/19 16:42:35	2.3
texnet2022tdou	9/30 08:04:05	2.8
texnet2022tdzc	9/30 13:16:05	2.4
texnet2022tiot	10/3 01:43:37	3.3
texnet2022vdsu	10/28 21:08:53	3.4
ESG local event	9/13 23:34:27	1.31



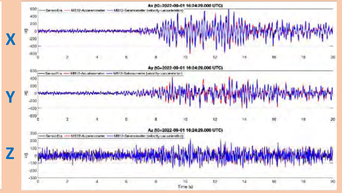
The traditional seismometers show a minimum amplitude of approximately 100µg, while stronger events seen nearly 80km away show ML between 3-4. The MEMS sensors, with a self-noise amplitude of 8-10µg (recently upgraded to 1ug), are suitable for monitoring in this area as this is well below the smallest recorded signal amplitude.

Results: 3C Data Comparison Station 1 v TexNet MB12

Proximal Event ML3.4@16km (Oct 28th)

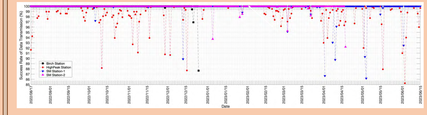


Distal Event ML4.6 @241km (Sept 1st)



The vertical and horizontal responses from the traditional seismometers and new MEMS sensors show excellent agreement for proximal and distal events. We observed excellent correlation between MEMS stations and traditional seismometers with the 3C trace data tracking very closely with one another. Velocity data has been converted to acceleration for display.

Results: System Reliability



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

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

Significance/Novelty

⇒**Fast to deploy**
⇒**Fast to retrieve**
⇒**Records instantly**
⇒**Event reports in seconds**
⇒**Low-cost**
⇒**6C motion**
⇒**3C orientation**
⇒**Fully autonomous**
⇒**Equivalent to seismometer**
⇒ **Wideband 0.03Hz-4Khz**

Acknowledgements

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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)