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A LOW-COST SEISMIC SENSOR NETWORK IN UMNUGOVI: THE RASPBERRY SHAKE 4D SOLUTION

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ABSTRACT

A preliminary monitoring network was established in the seismically active regions of Umnu-Govi province using high-sensitivity, low-cost Raspberry Shake 4D sensor devices. This network enhances earthquake monitoring capabilities and provides real-time information to local residents and authorities. Due to its affordability and ability to collect extensive data, the Raspberry Shake 4D is an ideal technological solution for remote areas of Mongolia with limited infrastructure.

The study evaluated the technical performance, data quality, timing and frequency accuracy, and reliability of the Raspberry Shake devices, as well as explored possibilities for future network expansion. Additionally, it assessed the potential and significance of extending the national seismic information network using cost-effective acceleration sensors. The research also aims to analyze the sensors' sensitivity, signal processing, and wave attenuation modeling.

INTRODUCTION

Umnugovi province is characterized by high seismic activity, a sparse population, and a vast territorial expanse. The successful installation of Raspberry Shake 4D accelerometer stations across all soums (districts) of the province has established a comprehensive seismic network, marking a significant advancement in Mongolia's earthquake monitoring system.

The connected stations provide high-precision, real-time recordings of seismic ground motions, enabling detailed studies of regional seismic characteristics and geographic variations. This network serves as a vital source of information necessary for improving local safety and reducing disaster risks.

Therefore, this seismic network plays an essential role not only in generating foundational data for seismic risk assessment but also in supporting the development of effective measures to enhance safety.

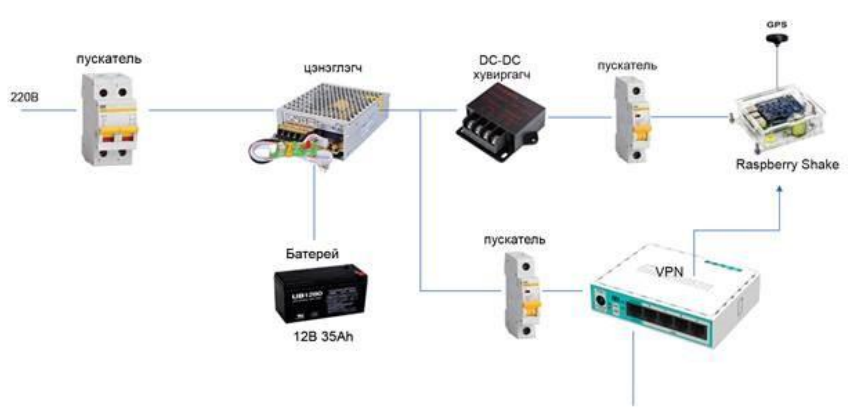


Figure. 1. Connection Diagram of the Raspberry Shake 4D Station

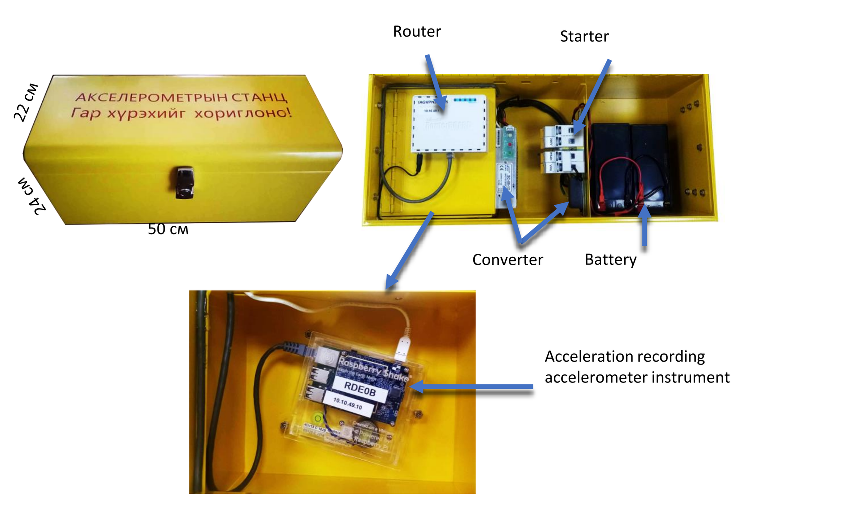


Figure. 2. Internal Structure and Layout of the Protective Metal Enclosure

RASPBERRY SHAKE 4D ACCELEROMETER NETWORK

An active effort is underway to establish a network of Raspberry Shake 4D stations throughout Umnugovi province. This network enables real-time evaluation of seismic vibrations from earthquakes occurring anywhere within the province, providing researchers with access to a unified data repository. Additionally, the public can receive timely online notifications about strong earthquakes, facilitating rapid hazard warnings.

Currently, the National Earthquake Information Center operates approximately 150 instruments at over 50 locations nationwide. These instruments are typically installed on bedrock to detect weak seismic events and to determine the location, magnitude, mechanism, and depth structure of earthquake sources.

The Raspberry Shake 4D stations measure seismic vibrations with high precision, playing a vital role in determining ground motion parameters such as peak acceleration, wave attenuation, and soil shaking characteristics. This information is critical for regional seismic hazard assessments.

In Umnugovi province, 22 accelerometer stations have been predominantly installed in urban areas, significantly contributing to the assessment of strong ground shaking and ensuring public safety.

Figure. 3. Installation Process of the Station

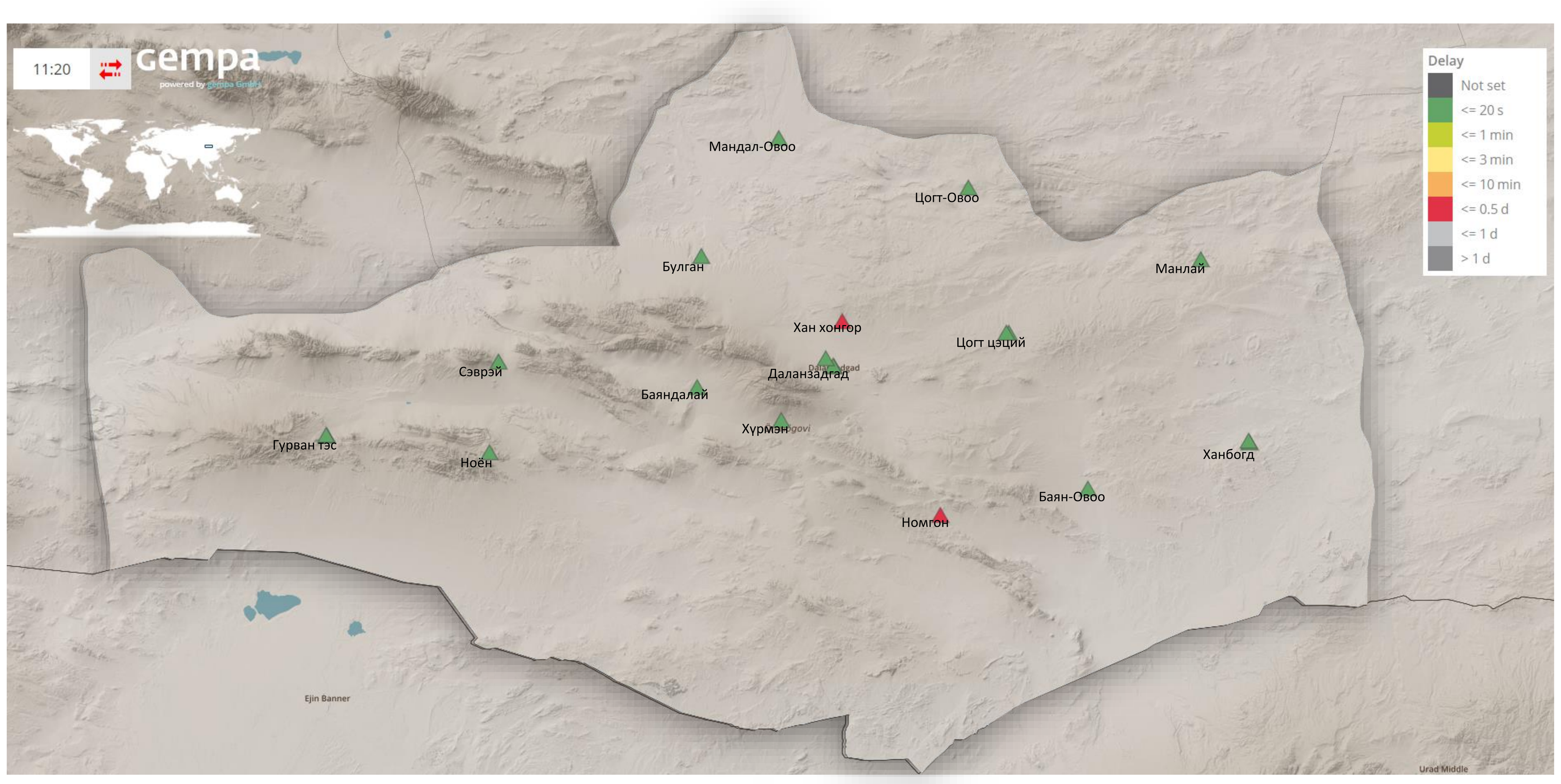


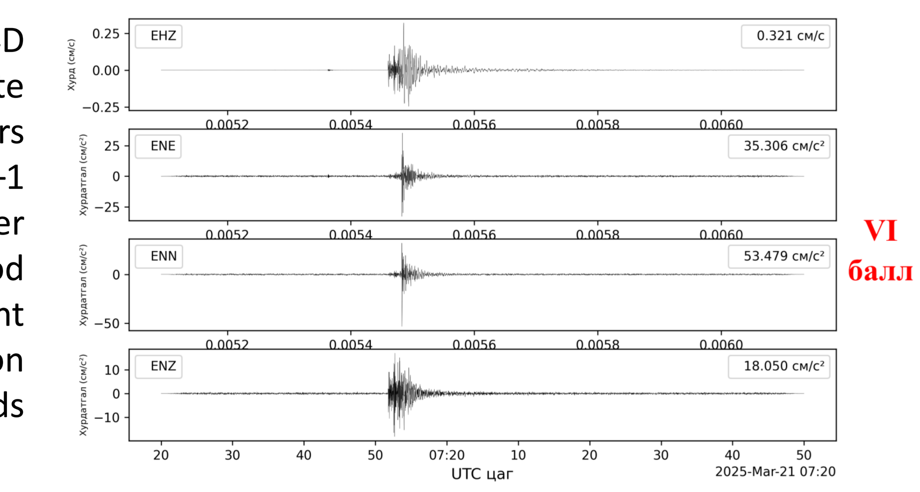
Figure. 4. Locations of Raspberry Shake 4D Stations Installed in Umnugovi Province

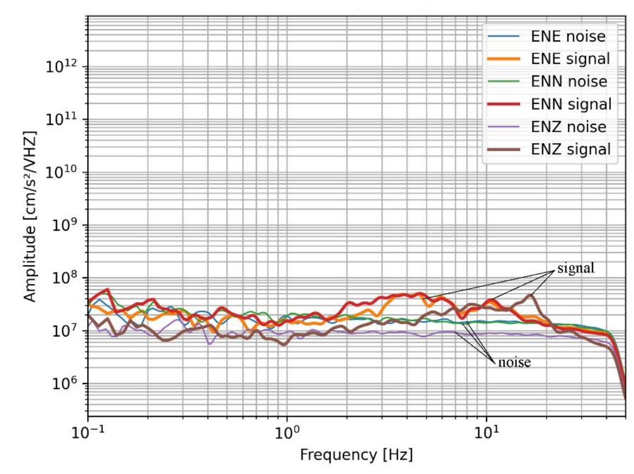
EXPERIMENT

Starting from March 19, 2024, we signed an agreement with Umnugovi province to install and operate Raspberry Shake 4D instruments across all soums (districts) of the province. The purpose of this deployment was to test data transmission and processing workflows, as well as to evaluate the sensors' sensitivity and operational conditions. Establishing this network enables detailed measurement of ground shaking, seismic wave attenuation, and soil vibrations, providing essential baseline data for regional seismic hazard assessments.

On March 21, 2025, at approximately 09:33 UTC, a magnitude 5.3 earthquake occurred about 20 km west of the center of Dalanzadgad soum, Umnogovi province. This seismic event was recorded by the Raspberry Shake 4D stations, and the data are currently under processing. The processed information will be used to evaluate the seismic hazard, ground motion intensity, and other seismic characteristics associated with the event.

Analysis of recordings from Raspberry Shake 4D stations in Umnugovi province showed that despite ambient noise interference, the accelerometers accurately recorded ground motions above 0.5–1 cm/s², while the velocity sensors detected weaker events, and comparison with short-period seismometer data confirmed good instrument accuracy, highlighting the need for further calibration against broadband stations and strong-motion records to improve precision.





Analysis of seismic recordings in Umnugovi using MEMS technology demonstrates that the instruments effectively capture high-frequency vibrations above 1 Hz, with building resonance influencing spectral peaks, all three components reliably recording signals near 3 Hz, and technical tests confirming a stable linear response from 2 to 40 Hz, though further calibration under strong ground motion is needed to ensure accuracy beyond this range.

№	Station name	Place name	Distance (km)	EHZ (cm/s)	ENE (cm/s^2)	ENN (cm/s^2)	ENZ (cm/s^2)	ball
1	R98B4	Bulgan sum	81					
2	R14F7	Bayan-Ovoo sum	170	0.002	1.377	1.414	0.778	II-III
3	R20FB	Tsogtsetsiin sum	116					
4	R87BA	Khurmen sum	28	0.321	35.306	53.479	18.05	VI
5	R6D6F	“Khanhongor sum	37	0.008	1.355	1.281	0.831	
6	RAA4B	Dalanzadgad	19	0.049	3.177	6.19	3.367	II-III
7	R6C1F	Gurvan Tes sum	258					
8	R5C4E	Gurvan Tes sum	256	0.001	1.249	1.24	0.796	
9	R4CEB	Khanbogd sum	249	0.003	1.321	1.089	0.71	II-III
10	R2C41	Khanbogd sum	124	0.003	1.363	1.528	0.892	II-III
11	R1A74	Sevrei sum	161	0.03	0.562	0.526	0.854	I-II
12	R9346	Nomgon sum	110	0.003	0.577	0.742	0.822	I-II
13	RB21D	Dalanzadgad	20	0.048	3.176	6.189	3.366	II-III
14	RDE0B	Tsogt Ovoo sum	136	0.005	0.766	0.641	1.011	I-II
15	RD869	Khanbogd sum	246	0.02	0.49	0.567	0.808	I-II
16	R5BD6	Manlai sum	224	0.004	0.509	0.548	0.842	I-II
17	RFD5F	Dalanzadgad	17	0.083	2.154	4.289	4.782	II-II
18	R77A6	Tsogtsetsiin sum	114	0.161	5.807	12.22	18.147	IV
19	RC852	Bayandalai sum	56	0.012	0.694	0.609	0.846	I-II
20	R55CE	Dalanzadgad	19					
21	RBD8B	Noyon sum	175	0.002	0.576	0.613	0.813	I-II

CONCLUSION

Our experimental measurements demonstrated that the MEMS-based accelerometer is capable of effectively detecting ground motions associated with strong earthquakes. The results indicate that the instrument can reliably register seismic waves with accelerations exceeding 1 cm/s² (approximately greater than intensity I on the seismic intensity scale) within frequency ranges above 1 Hz.

This performance meets the fundamental international requirements for strong-motion earthquake measurements, suggesting that a cost-effective accelerometer network can be feasibly deployed over a wide area. Such a network would enable simultaneous data collection from multiple sites, thereby improving the capability for rapid hazard assessment and real-time earthquake information dissemination.

Further work is required to evaluate the long-term operational stability of the instrument, as well as the effects of temperature and other environmental factors. Additionally, enhancing the data transmission system and central processing methodologies will support the integration of this low-cost solution into a national seismic monitoring framework.

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