New Seismic Unattended Small Size Module for Foot-Step Detection

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ABSTRACT

General Sensing Systems (GSS) has achieved outstanding and verifiable results in the design and performance of seismic systems with near zero false alarm rates for the detection of walking, running, and jumping persons. These results have been reported in various homeland security and military applications. GSS has been developing a new seismic, unattended small size module for footstep detection. This paper describes our design for the module, which includes the two-board and one-board versions—fitting into various consumer applications. Communication interface versions, which are used in the detection module, allow the communication with any wireless surveillance network. We also report on the preliminary lab and field-testing that was implemented in various conditions. We show that the new unattended, small size detection module demonstrates the same reliable performance as our previous full size systems.

Keywords: Seismic footstep detection, unattended near zero false alarm system.

1. INTRODUCTION

Near zero false alarm seismic surveillance systems can be used in various homeland security and military applications. GSS has designed and developed a seismic system modification for perimeter and border protection [1-4]. This system has the broadest application area. However, for many tactical situations and for many action scenarios, the mobile, unattended, small size and wireless seismic surveillance and reconnaissance systems become indispensable.

The design of mobile unattended systems can vary greatly. In all cases, however, the main and the most important part of these systems is a single unattended, small size module. Its detection and discrimination capability plays a key role for efficiency, reliability and rationality of the whole mobile system. In fact, the real capabilities of the single module should determine the design and architecture of the integral mobile system. That is why GSS has focused on the design and development of such an unattended seismic detection module.

The main requirements for the unattended seismic detection module are:

- Small size
- Low power consumption
- Limitation of the memory size and processing speed of the used microprocessor
- Capability of various target detection and identification
- Relatively high detection range
- Wireless communication
- Capability of working directly on the ground surface (non buried installation)
- Installation simplicity

According to the above-mentioned requirements, GSS has developed both hardware and software for the unattended seismic detection module. GSS designed and manufactured two versions of the seismic module in order to fit different security applications.

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In this paper, we report on the various designs of the GSS seismic unattended small size module for footstep and other moving target detection. We also report on the preliminary testing of such a module in the lab and real environment conditions. We illustrate our results with real detection range data for footstep detection and with the examples of detection of other targets.

2. RESULTS AND DISCUSSIONS

2.1 Hardware design

2.1.1 Seismic amplifier

Using the seismic geophone type GS-20DX, GS-14-L3 [5] or any other electro-dynamic velocimeter in the real environment gives us a very low and weak electric signal. Therefore, a significant pre-amplification should be used to supply the signal to an analog-to-digital converter (ADC) and to consequent processing, especially when detecting low amplitude seismic footstep signals.

For development purposes, GSS has designed and tested a two-channel seismic amplifier. One channel allows the amplification of the seismic signal. The other channel allows the preprocessing of the signal in order to reduce computing requirements of the micro controller. This amplifier was created based on the Analog Devices operational amplifier OP295. This amplifier has a symmetrical input and variable high gain in the range of 10^3 to 10^5. We can use this amplifier for amplifying a signal from any electro-dynamic seismic sensor.

This amplifier has an additional non-symmetrical input. It also allows us to use in the future the novel GSS miniature seismic sensor that has significantly better sensitivity and frequency characteristics than the existing seismic sensors [6-10].

The amplifier has two outputs. One output emits a raw gain signal. The other output provides the gain signal with additional preprocessing. A final decision about which output is better to use can be made during testing of the amplifier and micro controller breadboards.

2.1.2 Processing micro controller

For data processing and decision making about the presence of trespassers or other targets in the detection area, a special micro controller is used. This micro controller is based on the high-performance, low-power AVR® 8-bit micro controller ATMega128. This device has advanced Reduced Instruction Set Computing (RISC) architecture, 128-Kbyte self-programming Flash Program Memory, 4-Kbyte SRAM, 4-Kbyte EEPROM, an 8 Channel 10-bit A/D-converter, up to 16 MIPS throughput at 16 MHz, and 2.7 – 5.5 Volt operations.

The micro controller main board provides programmable comparator circuit for using sleep mode and watchdog for the protection of a seismic detector from specific software or hardware failures that may cause the detector to stop responding and function correctly. A standard serial interface is used for the connection of the main board to the laptop for processing parameter loading and for the tuning of the whole device by preliminary testing.

The main board has 3 LEDs of various colors (red, green, yellow), which correspond to different classes of the detected target. These LEDs simplify the seismic detector tuning and indicate its functionality during installation. Initial signal sampling frequency is 256 Hz. The length of the processing signal is 4 sec. The main processing characteristics can be chosen during testing.

The components placement and layout of the seismic amplifier and micro controller boards (top sides) are shown in Figure 1 below.

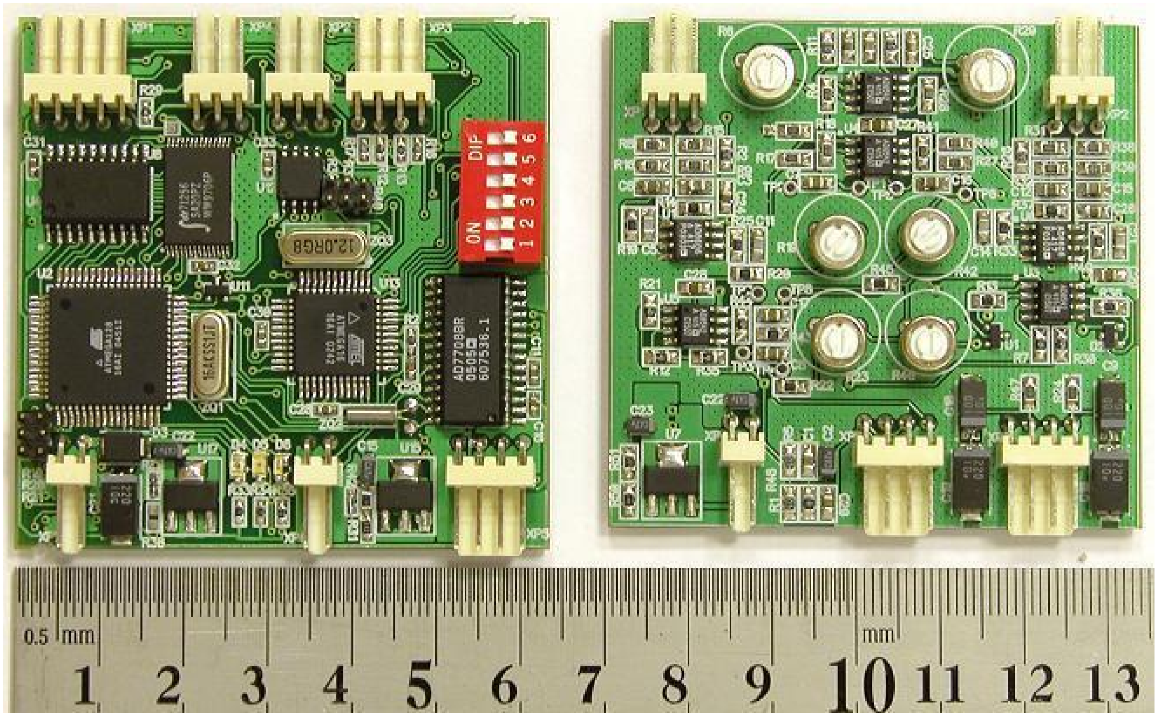

Figure 1. Top sides of the micro controller and amplifier breadboards.

The amplifier and controller power supply should be in the range of 6.3-12V. Both boards have an internal 5V DC voltage stabilizer. The micro controller's current consumption in the data processing mode is 160 mA. The micro controller's current consumption in the idle mode is 40 mA. The seismic amplifier has a power consumption about 6mA per channel.

The controller Input should be connected to the amplifier output. In the main software version, the controller makes "normal signal processing" (without preprocessing in the amplifier breadboard) and for this reason the amplifier output #1 should be used. The peak detector output (output #2) is reserved for additional implementation. The flat connection cable allows to connect the boards in a "sandwich" style (preferable orientation) and on one level (see Figure 2a and Figure 2b below).

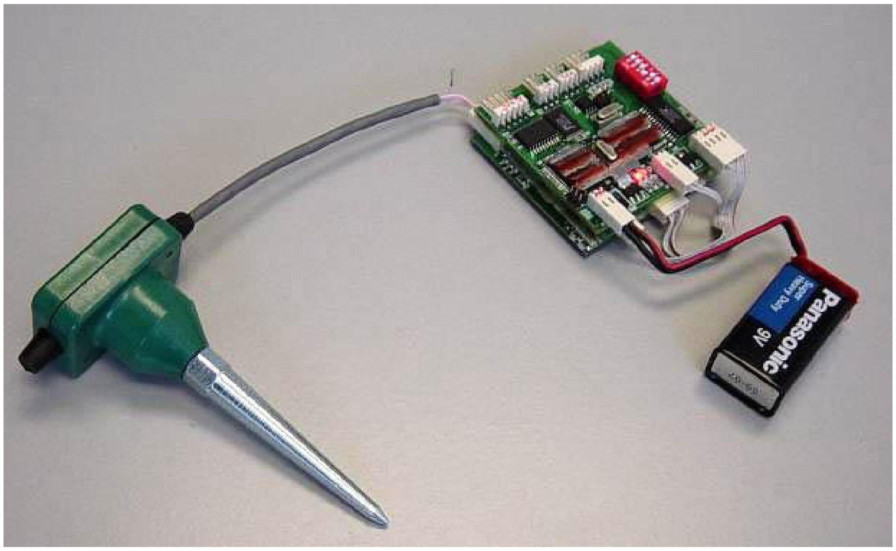

Figure 2a. The connected boards ("sandwich" style).

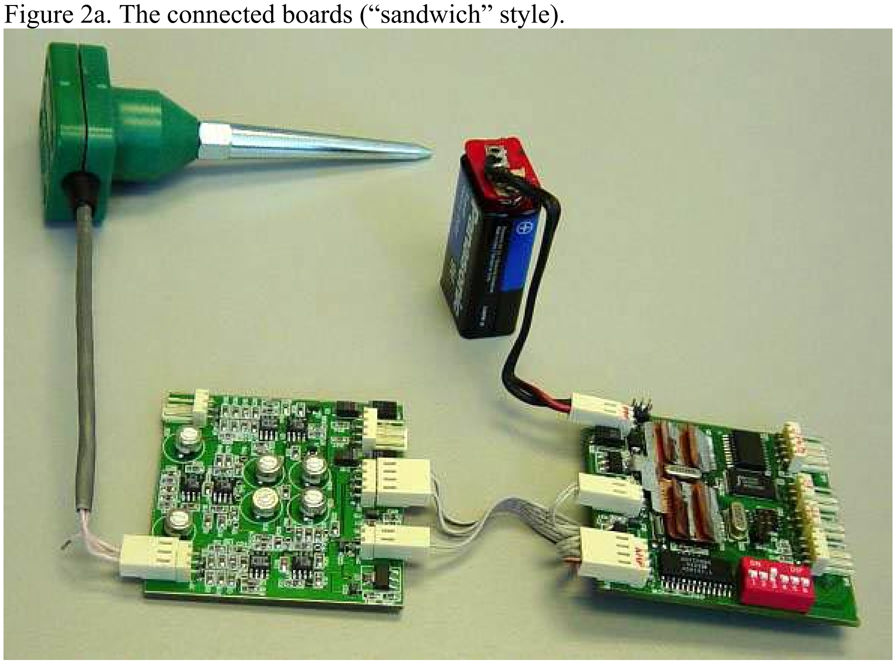

Figure 2b. The connected boards on one level.

The amplifier output has low resistance (operational amplifier) and with a short cable length, extra shielding is recommended but not strongly required. In case of the strong external electromagnetic fields, a total controller and amplifier shielding is required because high amplification gain is up to 100,000. Sensors should be connected to the corresponding amplifier connectors. A central pin in these connectors could be used for sensor cable shielding connection in case of a long cable. In case of a short cable (up to 0.5m) shielding is not strongly required because the amplifier has a differential input.

A cable for the PC serial connection should be connected to the corresponding connector RS232 on the micro controller board. The RS485 connector is reserved for the possible long distance communication in the future network.

For field tests, breadboards with a battery were placed inside the plastic box. The Geophone GS-14LS was used in this standard case (Figure 3).

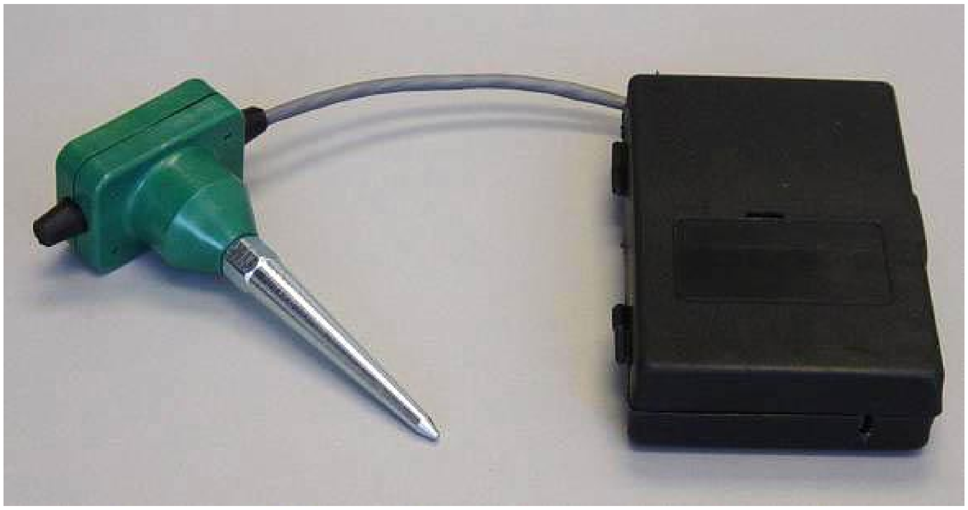

Figure 3. Device used for field tests.

2.2 Software design

GSS has designed two main software programs. The first program was designed for signal processing and decision-making. This program was loaded in the processing micro controller. The second program was designed for the adjustment and tuning of the seismic detector micro controller and for monitoring of the processing results. This program is used on a laptop during the various seismic module testing.

The software for the micro controller is based on GSS's proprietary footstep detection algorithm [3]. This algorithm was tested on a full size computer and has showed very reliable footstep detection with a near zero false alarm rate [1]. In fact, GSS has provided a solution to the main problem of almost all trespasser (terrorist) detection systems. GSS has developed a reliable detection method, which can be used for real-time detection.

The GSS method is based on a new, previously unknown method for signal processing. In fact, this method is the computing realization of the methods for analysis of field records and decision-making, which are used by an experienced investigator during visual, long-term, overall and detailed analysis of such records. Up-to-date computers already allow to realize all exclusive possibilities of the analysis available for a person in his work in real time.

The GSS approach is capable of interpreting the physical data as well as if it was processed by an experienced operator. In addition, the use of the GSS software allows this interpretation in real-time, in contrast to the delays experienced when an operator tries to perform similar tasks. Due to new features of the software, the new security system reliably detects a trespasser at any point of detection zone and functions at the level of interference, even if it is equal to the level of signals. Interference of any intensity does not cause false alarms.

Such a software is unique and is used neither in any information electronic system nor in any other systems for data collection and processing of data used to monitor an environment (i.e., detection and classification of objects and determination of environmental conditions).

2.3 Seismic detector testing results

The GSS seismic detector was tested in lab and field conditions in Westchester County, NY during September 2005 to March 2006. The proprietary work was monitored using a laptop tuning software and by color LEDs on the micro controller breadboard (Red – "Alarm", Green – "Shock", Yellow – "Noise"). These signals indicate the following:

- Alarm – trespasser footsteps (presence of a walking or running person in the detection area).
- Noise – high noise levels for a long time-duration.
- Shock – high noise levels for a short time-period.

In addition, laptop-monitoring software shows a time of the first signaled contact with the target (date, hours, minutes, seconds) and duration of the signal contact with the target (seconds). All information is renewed every two seconds. The laptop software saves all monitoring and processing data.

One of the field test areas at the Hudson River Bank in Yonkers, NY is shown in our paper [11]. An example of the other low noise testing zones is Ward Pound Ridge Reservation, Westchester County, NY and is shown in Figure 4 below.

Figure 4. Field test environmental conditions (example)

All these areas were chosen in order to have the capability to detect not only walking or running person, but also moving vehicles and other kinds of targets.

The testing has shown that the seismic detector actually does not have false Alarm during several hours while located in the proximity of the parkway, highway roads or railway. In addition, during many working hours in lab conditions, the detector did not initiate "Alarm" signal.

A possible detection range was estimated during testing in both the high-noise (Hudson River Bank) and the quite area in the park zones (Ward Pound Ridge Reservation) of Westchester County, NY. The distance to the nearest road was from 25m in high-noise area to 100m and more in a quite area.

During testing, the person began walking from far away (distance to the sensor more than 40m). Then the person walked right near the geophone GS-20DX, connected to a seismic detector, and walked away. Typically, the contact time with the target in a quite area was about 30 seconds. Therefore, a walking person was detected for about 60 steps—equal to about 40m. In other words, the target was detected and an "Alarm" was initialized in circuit with diameter about 20m (this diameter represents the typical detection range of surveillance systems). Of course, that circuit was "shifted" from sensor in a walking direction at about 10m because the seismic detector needs time for data collection and data processing before decision-making.

The following Table 1 is an example of a real-time protocol, which is formed by monitoring software.

Table 1. Test performed on March 24, 2006 in Ward Pound Ridge Reservation.

03.24. 14:35:08	SH	03.24. 14:36:21	SH
03.24. 14:35:10	SH	03.24. 14:36:23	SH
03.24. 14:35:12	SH	03.24. 14:36:25	SH
03.24. 14:35:14	SH	03.24. 14:36:27	SH
03.24. 14:35:16	SH	03.24. 14:36:29	SH
03.24. 14:35:18	SH	03.24. 14:36:31	SH
03.24. 14:35:20	SH	03.24. 14:36:33	SH
03.24. 14:35:22	SH	03.24. 14:36:35	Alarm-R-2s SH
03.24. 14:35:24	Alarm-R-2s SH	03.24. 14:36:37	Alarm-R-4s SH
03.24. 14:35:26	Alarm-R-4s SH	03.24. 14:36:39	Alarm-R-6s SH
03.24. 14:35:28	Alarm-R-6s SH	03.24. 14:36:41	Alarm-R-8s SH
03.24. 14:35:30	Alarm-R-8s SH	03.24. 14:36:44	Alarm-R-10s SH
03.24. 14:35:32	Alarm-R-10s SH	03.24. 14:36:46	Alarm-R-12s SH
03.24. 14:35:34	Alarm-R-12s SH	03.24. 14:36:48	Alarm-R-14s SH
03.24. 14:35:36	Alarm-R-14s SH	03.24. 14:36:50	Alarm-R-16s SH
03.24. 14:35:38	Alarm-R-16s SH	03.24. 14:36:52	Alarm-R-18s SH
03.24. 14:35:40	Alarm-R-18s SH	03.24. 14:36:54	Alarm-R-20s SH
03.24. 14:35:42	Alarm-R-20s SH	03.24. 14:36:56	Alarm-R-22s SH
03.24. 14:35:44	Alarm-R-22s SH	03.24. 14:36:58	Alarm-R-24s SH
03.24. 14:35:46	Alarm-R-24s SH	03.24. 14:37:00	Alarm-R-26s SH
03.24. 14:35:48	Alarm-R-26s SH	03.24. 14:37:02	Alarm-R-28s SH
03.24. 14:35:50	Alarm-W-28s SH	03.24. 14:37:04	Alarm-R-30s SH
03.24. 14:35:52	SH	03.24. 14:37:06	Alarm-R-32s SH
03.24. 14:35:55	SH	03.24. 14:37:08	Alarm-W-34s SH
03.24. 14:35:56	SH	03.24. 14:37:10	SH
03.24. 14:35:59	SH	03.24. 14:37:12	SH
03.24. 14:36:01	SH	03.24. 14:37:14	SH
03.24. 14:36:03	SH	03.24. 14:37:16	SH
03.24. 14:36:05	SH	03.24. 14:37:18	SH
03.24. 14:36:07	SH	03.24. 14:37:20	SH
03.24. 14:36:09	SH	03.24. 14:37:22	SH
03.24. 14:36:11	SH	03.24. 14:37:24	SH
03.24. 14:36:13	SH	03.24. 14:37:26	SH
03.24. 14:36:15	SH	03.24. 14:37:28	SH
03.24. 14:36:17	SH	03.24. 14:37:30	SH
03.24. 14:36:19	SH	03.24. 14:37:32	SH

During demo testing in a high-noise area, the person walked in a similar manner. The detection range in such an area depends strongly on the noise level nearby, i.e. cars, trains, etc. Therefore the detection range was estimated to be 10 to 20m. The maximum detection range of 20m corresponds to a situation when cars and trains were far away from the seismic sensor (50m to the nearest car, and more than 1000m to the nearest train).

All the above mentioned results show that the designed seismic detection module fits many possible consumers' detection requirements.

2.4 Processing micro controller (advanced version)

At the present time, GSS is testing a second generation of the small size unattended seismic detection module with significantly reduced power consumption and smaller size. This module has a single board with both an amplifier and a micro controller electronic circuit. This single-board device incorporates the new low voltage supply microchip for the micro controller, which has enough memory for the signal processing algorithm and processing data. Components placement and layout of such a board (top and bottom sides) are shown in Figure 5 below.

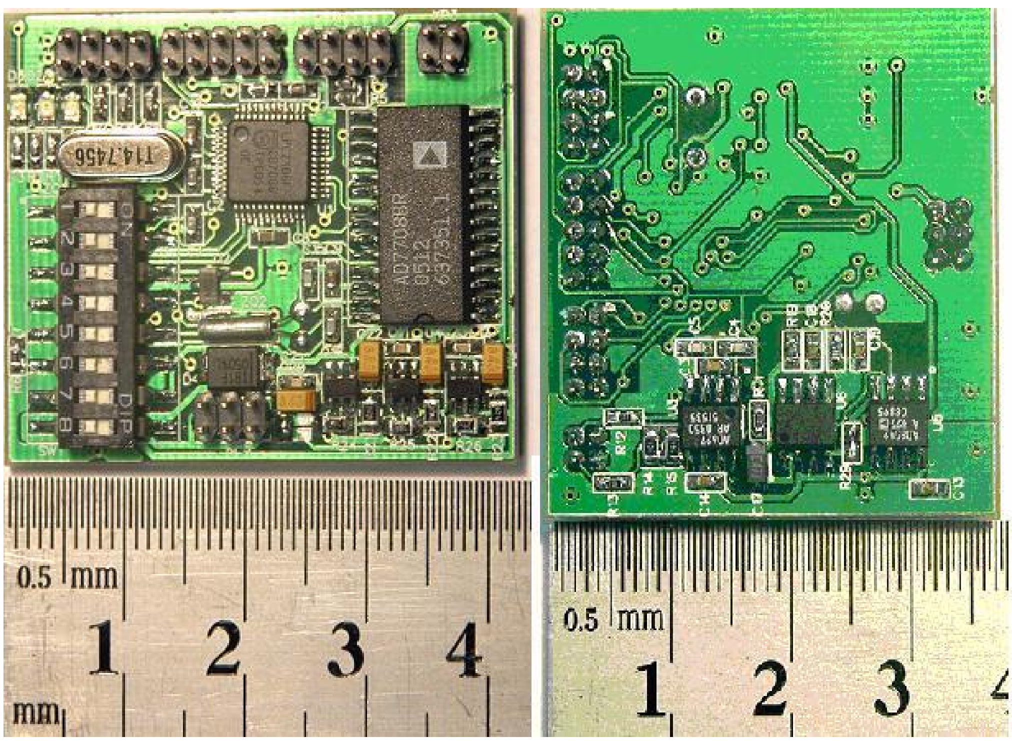

Figure 5. Advanced latest version of the seismic detection module board.

The software for this seismic detection module has the same structure, as described above for the first version of the detection module. We hope that its detection capability will be at the same high level, but average power consumption will be less than 45mW.

3. CONCLUSIONS

The presented work shows that it is possible to design and manufacture a small-size, unattended seismic detector, which uses complex mathematical algorithms for footstep detection. Until now, such sophisticated algorithms were used only in "full-size" computers. Such algorithms provide very reliable footstep detection with extremely low false alarm rate.

The use of the analog signal preprocessing in addition to signal amplifying does not make sense because of the loss of critical target signal information. The target signal information should be used for decision-making, especially for detection of the various target classes.

The size and power consumption of the seismic detector can also fit the many possible consumer detection requirements [12-14]. The use of the modified detection algorithm will also help to efficiently improve the performance of the small-size, unattended seismic detector in terms of the detection capability of various target classes.

In the future, the use of the GSS-miniature sensor [6-10] can additionally improve the unattended seismic detector performance characteristics.

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