Field Testing of New Unattended Small Size Seismic Module for Various Target 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 and running persons. These results were realized in a number of detection systems and in particular in small size seismic detection modules. Preliminary testing of these seismic modules in various environment noise conditions shows that such small unattended modules can be successfully used for other target detection. Potential target sets can include light and heavy vehicles, helicopters, aircraft, and ships. This paper describes preliminary results of such target detection and preliminary experimental data about corresponding detection range. We show that the new unattended, small size detection module demonstrates reliable performance in various environment conditions.

Keywords: Seismic security and reconnaissance systems

1. INTRODUCTION

In our previous papers we have shown that seismic systems can be used for various target detection [1, 2]. Such targets could be personnel, light and heavy vehicles, helicopters, aircrafts, ships, etc. In testing such target detection capability, we have used both a “full size” seismic detector, based on a PC, and a small size seismic detection module. GSS continues to develop a new generation of the small size seismic autonomous detection module with extremely low power consumption, high detection capability, and low false alarm rate. Various combinations of such detection modules allow the design of practical and reliable seismic detection systems for security and military applications. These systems can be wired or wireless, mobile and autonomous, or stationary.

Seismic fields from various targets have different characteristics [2-4]. Based on our previous data, we have analyzed small detector capability of various target detection. These characteristics are used for the redesign and tuning detection algorithm preloaded in GSS new small size seismic autonomous detection modules. The main purpose was to not only detect dangerous targets but to also ensure their identification. The existing differences between target signal characteristics allow this to be accomplished.

In this paper, we report on some field testing results of the above mentioned targets and present preliminary experimental data about the corresponding detection range of our last generation of the small size seismic detection module. We illustrate our results with field test records. We also report on any seismic sensors and seismic system requirements for various target detection.

2. RESULTS AND DISCUSSIONS

2.1 Hardware description

2.1.1 Geophones

Throughout all testing, we used the commercially available GS-20DX geophone (seismic sensor) produced by Geo Space Corporation [5]. One of the important characteristics of this geophone is frequency bandwidth, which is 8.0-1500Hz according to manufacturer’s data [5]. We also attempted to use the GS-14L3 commercial geophone, but it

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Unmanned/Unattended Sensors and Sensor Networks III, edited by Edward M. Carapezza,
Proc. of SPIE Vol. 6394, 63940D, (2006) · 0277-786X/06/$15 · doi: 10.1117/12.714301

proved to be less efficient because of its very high natural frequency (28Hz) which can dramatically reduce the detection range of the heavy targets (i.e., heavy vehicles) that produce a lot of low frequency seismic vibrations.

2.1.2 Processing micro controller

At the present time GSS is testing the second generation of the autonomous seismic detection module that is significantly reduced in size and power consumption. This module has a single board with both an amplifier and a micro controller electronic circuit. This single board device incorporates the LPC2106 low voltage microchip for the micro controller, which has enough memory for the signal processing algorithm and processing data. The general view of this board (top and bottom sides) is shown in Figure 1 below.

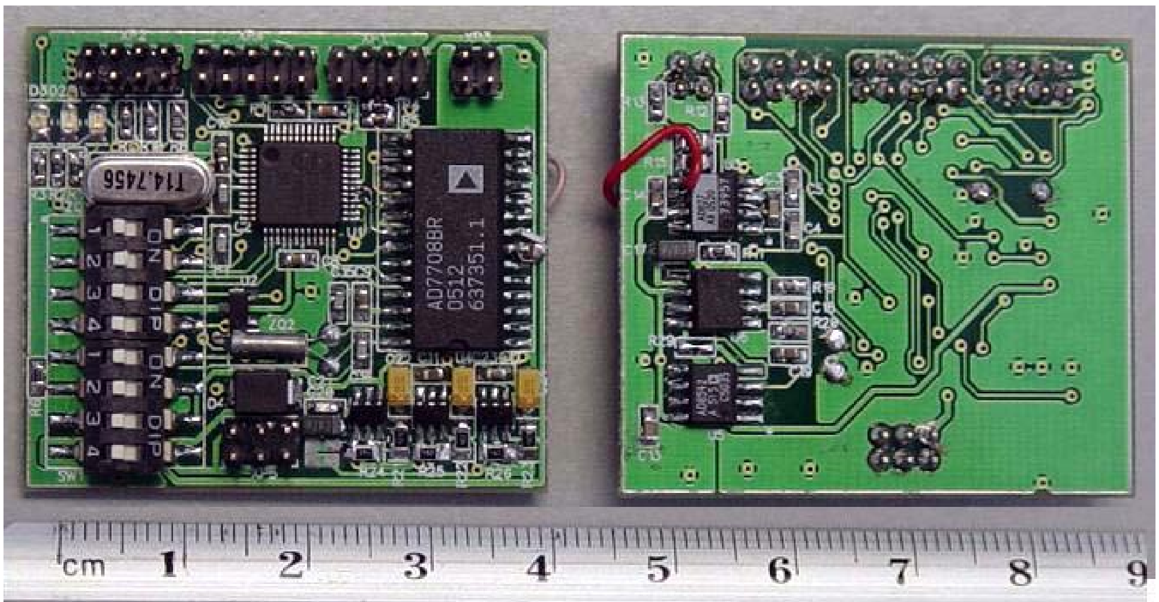

Figure 1. The GSS seismic detection module board.

For field testing, this board was placed in an enclosure box with the red, yellow and green LEDs on the top surface, along with the connectors for the seismic sensor and power supply battery. The LEDs are used for expedient preliminary signalization about the target class and noise-level conditions. For example:

- Red – footstep alarm (presence of a walking or running person in the detection area)
- Yellow – heavy vehicle alarm
- Green – light vehicle alarm

Alternately, the LEDs could be tuned to signal the following alarms:

- Red – footstep alarm (presence of a walking or running person in the detection area)
- Yellow – high noise level for a long duration (“noise”).
- Green – high noise levels for a short duration (“shock”).

The box also has a connector for the interface communication cable to the laptop for making signal records and for adjustment of the processing parameters. The last version of the box is shown in Figure 2.

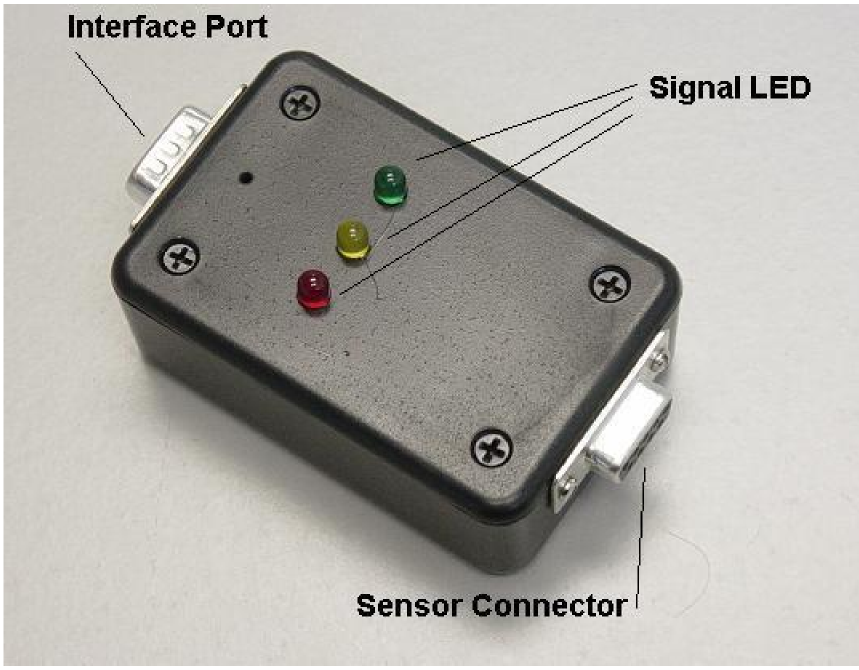

Figure 2. Detection hardware box with signal LEDs, a sensor connector and an interface port.

The full set of the hardware for working in the field is shown in Figure 3 below.

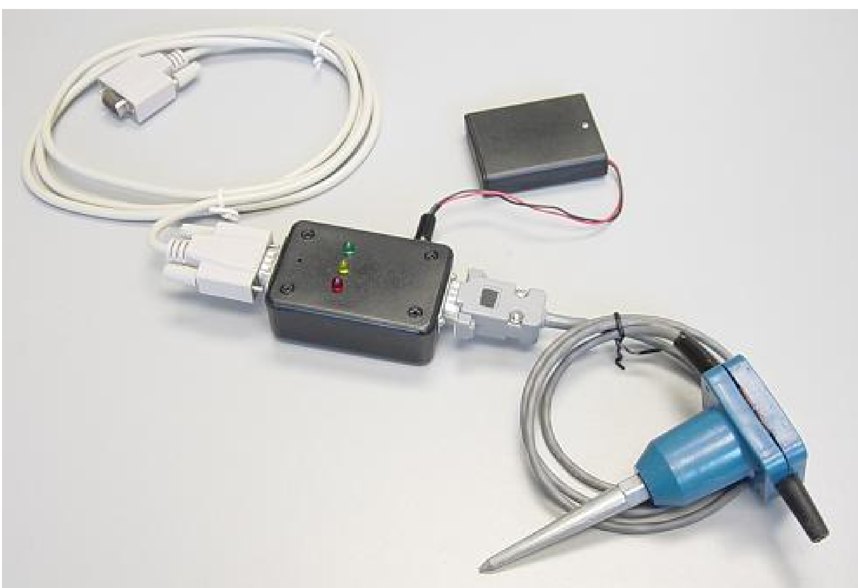

Figure 3. Field testing hardware comprising geophone, processing box, battery, and a PC interface cable.

The software preloaded in the described seismic detection module has the same architecture as was described in our paper [6] for the first generation of the detection module. The detection capabilities are at the same high level, but the average power consumption of the last generation detector is much lower and actually does not exceed 15mW for a reasonable number of targets in the detection area.

2.2 Field test environment conditions

One of the field test areas was at the Hudson River Bank in Yonkers, NY as described in our paper [2]. During our field tests at this site, we investigated the seismic detector capability and signal characteristics for the following moving targets and distances:

- Walking and running person on a dirt and asphalt road (1m and up),
- Light and relatively heavy vehicle on dirt and asphalt road (5m and up),
- Helicopter flying along the Hudson River (600m and up),
- Ship moving along the Hudson River (400m and up),

For seismic system development, it is critical to obtain signal records of targets in similar environment conditions. This allows to make an objective comparison of the various target signals and to design reliable seismic detection and discrimination modules and systems.

The other testing zone used was at the Ward Pound Ridge Reservation, Westchester County, NY. An aerial photo of this field testing area [7] is shown in Figure 4 below.

Figure 4. Aerial photo of the field testing area in Ward Pound Ridge Reservation, Westchester County, NY.

The second testing area was used for footstep, light and heavy vehicle detection and identification of moving targets on the dirt and asphalt roads. At both testing sites, geophones were installed right on the ground with the grass surface, see Figure 5 below.


Figure 5. General Sensing Systems testing hardware.

The layout of the seismic sensor relative to traffic in the second testing area is shown in Figure 6 below.

Figure 6. Layout of the seismic sensor relative to traffic in the second testing area.

We field tested various heavy vehicles. An example of such vehicles is shown in Figure 7 below. The seismic characteristics of such of a heavy vehicle is analogous to those of a missile launcher.

Figure 7. Heavy truck on asphalt road

2.3 Seismic detector testing results

2.3.1 Walking person

During testing, the person began walking from far away (distance to the sensor of more than 60m). 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 low noise area was about 30 seconds. Therefore, a walking person was detected for about 60 steps—equivalent to about 40m. In other words, the target was detected and an "Alarm" was initialized in an area with a diameter of about 20m (this diameter represents the typical detection range of surveillance systems). Of course, this area was "shifted" from the sensor in a walking direction of about 10m because the seismic detection module needs time for data collection and data processing before decision making. For a person walking on the asphalt road next to the geophone installed in the grass close to the asphalt road, the detection range is 10-15 meters depending on the quality of asphalt road.

2.3.2 Light and heavy vehicles

For many important applications, the detection range for various targets should be about the same given tactical and installation requirements. Therefore our main goal was to make sure that light and heavy vehicles can be reliably detected at the same distance as for the walking person (20 meters). Distances of more than 20 meters were also investigated.

The testing results in both areas show that light and heavy vehicles are reliably detected at the distance of 20m and lower regardless of pavement quality (dirt and/or asphalt road). Only for light vehicles moving with a speed of less than 30 km/h and for very smooth asphalt pavement, this 20m detection range may almost be at the maximum. On the other hand, such conditions are practically impossible for most significant applications.

The detection range for heavy vehicles is usually not less than 75 meters even on an asphalt road. On a dirt road, the detection range can increase dramatically depending on the road smoothness, vehicle speed and its weight. In the case of a heavy truck moving at a high speed moving on a non-paved road, the detection range can increase up to ten times and more. For carefully driven light vehicles, the detection range on the dirt road ranges from tens of meters up to a few hundred meters. An increase in speed and a decrease in road smoothness lead to a detection range increase.

Examples of the raw signals for light and heavy vehicles are shown in Figure 8 below.

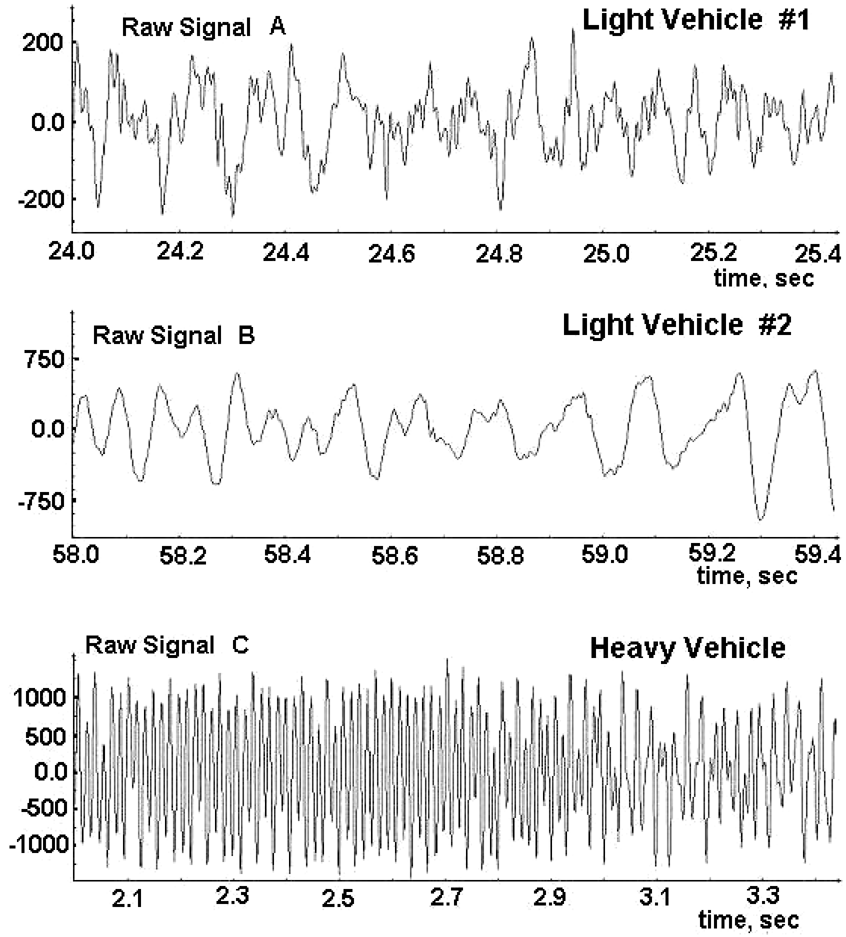

Figure 8. Examples of the raw signals for light and heavy vehicles.

The records shown in Figure 8 correspond to a distance between the seismic sensor and vehicles of about 5 to 15m. The speed of all vehicles was low (about 15 to 20km per hour). Figure 8A shows the signal from the vehicle that was moving in high gear with constant speed. Figure 8B and Figure 8C show the signals from vehicles that were moving in low gear and accelerating. All vehicles were moving on an asphalt road. The represented signals show that for the identification of light and heavy vehicles, even for brief records spectral analysis can be used. This is valid only for short distances between the sensor and vehicles. In many real applications, when a higher detection range is desirable, other approaches should be used for vehicle identification.

2.3.3 Helicopter

A helicopter is an interesting object for many applications, since on the one hand it can be a target, and on the other hand, it can act as an interfering object in a seismic detection zone for vehicles or people. A comparison of the amplitude spectra of the vehicles and helicopter is shown in Figure 9.

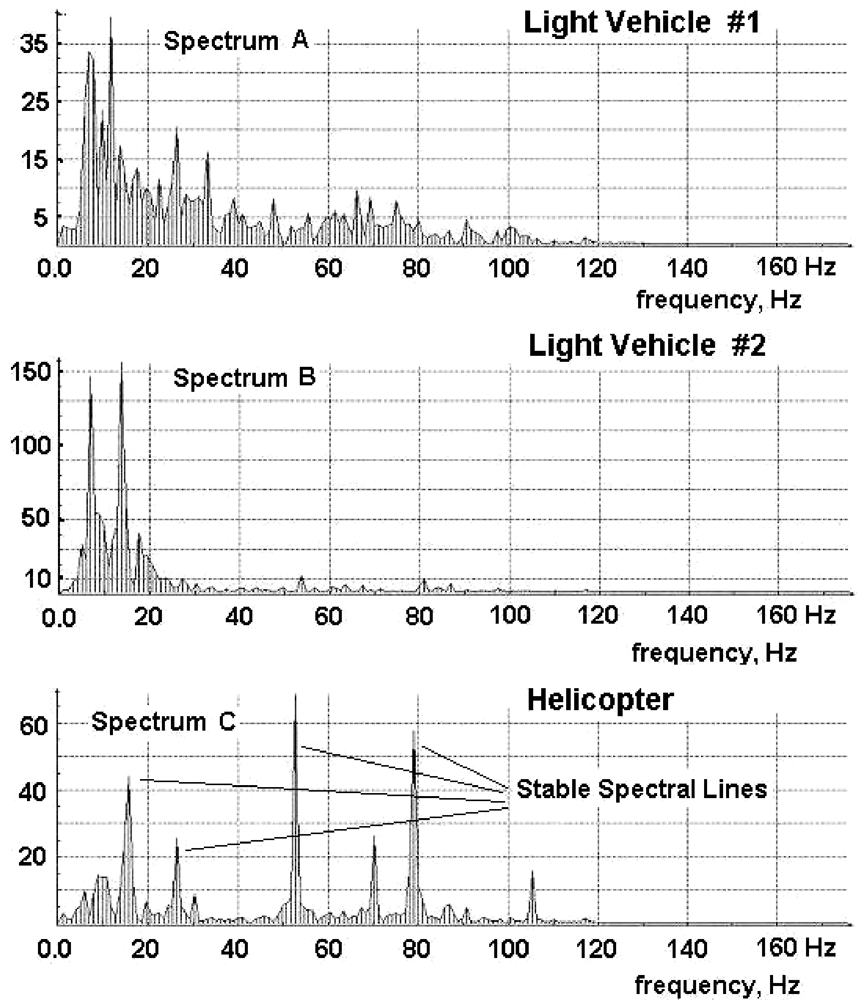

Figure 9. Signal spectra for various targets (A, B – light vehicles, C – helicopter).

The above data clearly shows that a helicopter can be reliably identified among various vehicles since it has very stable, narrow and strong spectral lines in its amplitude spectra at frequencies between 20 and 120Hz. The detection range for the helicopter in a quiet area is up to 1,000-2,000 meters. Such a detection range can be achieved only if other targets are not present in the seismic detection area.

3. CONCLUSIONS

The presented work shows that it is possible to design and manufacture a small-size, unattended seismic detector, which when using complex mathematical algorithms can detect not only footsteps (walking or running persons) but also various seismic signal producing targets. Until now, such sophisticated algorithms were used only in “full-size” detection systems. At the present time, we have a real capability to design and manufacture a small size seismic detection module for such purposes.

The preliminary research showed that the processing capability of the small detection module satisfied requirements to detect at least three various targets, i.e. walking person, light and heavy vehicles. The target signal information represented in this paper and in our previous work [2] should be used for decision making. The preliminary assessment of the detection range shows that a small size detection module satisfies corresponding requirements for many security and military applications.

The size and power consumption of the seismic detector can also fit many possible consumer detection requirements [8-11]. The redesigned detection algorithm also helps 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 capabilities and characteristics.

ACKNOWLEDGEMENTS

Dr. Ed Carapezza of DARPA is acknowledged for general ideas of the presented small size seismic detection module design. Mr. Kevin Benson, Mr. John Finklea, and Mr. Charles Stuewe of Signal Technology are acknowledged for their recommendations in the design of the seismic module. This work was supported in part by Signal Technology.

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