# Seismo-acoustic detection of land mines

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## Introduction

The detection of mines is classically done by means of a magnetic detector. On the field, this kind of equipment is liable to false alarms and can fail to detect non-metallic mines. For these reasons we have investigated detection methods based on other physical principles. Among those, acoustic and seismic methods are highly complementary to the electromagnetic or infrared methods and have an interesting potential for medium-range detection.

During previous studies, we investigated two acoustic-seismic methods. The first one is based on the detection of an echo when the ground is subjected to a seismic wave [1]. The second method is based on a differential holographic visualization [2]. These two methods are not well adapted to a practical use on the field but they have demonstrated their capability to detect buried objects by means of mechanical waves. A new method based on high-power acoustic emission associated with a velocity measurement of the ground by a laser vibrometer has been recently published [3]. The results presented in this paper aim to verify the interest of this method in various experimental configurations.

## Experimental set-up

An aerial acoustic wave is generated by a loudspeaker in the direction of the ground (Figure 1). The acoustic signal is a white noise with a level of 105 dB SPL. The vibrations of the ground have been measured with the help of a laser Doppler vibrometer. For the first experiments, the emission and the acquisition are controlled by a spectrum analyzer. As the mine container has mechanical characteristics which differ from the surrounding ground, it modifies the vibration pattern of the ground surface locally. We have looked for resonance frequencies in the 50-850 Hz range.

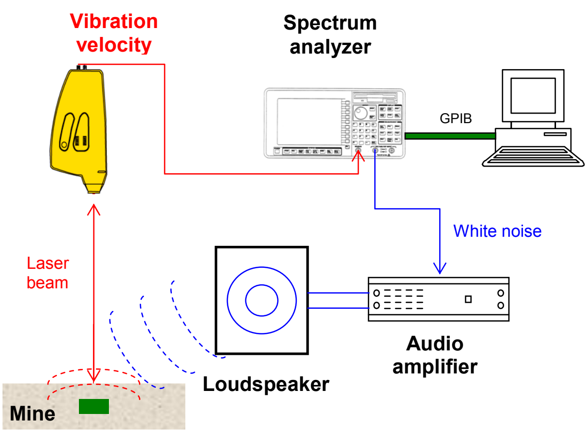


**Figure 1:** Experimental set-up

## Experimental results

### Influence of the depth of burial

The objectives of the first experiments are to quantify the influence of the depth of burial of the mine. These trials take place outdoors in a big sand box (6 x 3 x 1 m). The vertical component of the vibration velocity is measured on the center of the mine. We use a generic mine which has a simple cylindrical shape to facilitate further theoretical investigations.

For this experiment, a hole is dug in such a way that the top of the mine is 4 cm under the ground level (Figure 2). A first measurement is carried out on the upper part of the mine which is uncovered (b). After the mine has been covered with a layer of 0.5 cm of sand, a new measurement is taken, and so on, until the mine is covered by 4 cm of sand (c).

The velocities measured under these conditions (b and c) are much higher than that measured on the ground without a buried object (a). A slight decrease in the amplitude and in the resonance frequency is noticeable when the thickness of the ground covering the mine increases. The main resonance frequency is observed in the 70-130 Hz range when the mine is buried, and at approximately 220 Hz when the top of the mine is visible (Figure 3).

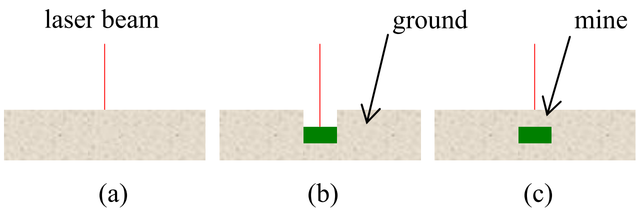


**Figure 2:** Configurations tests with or without buried mines

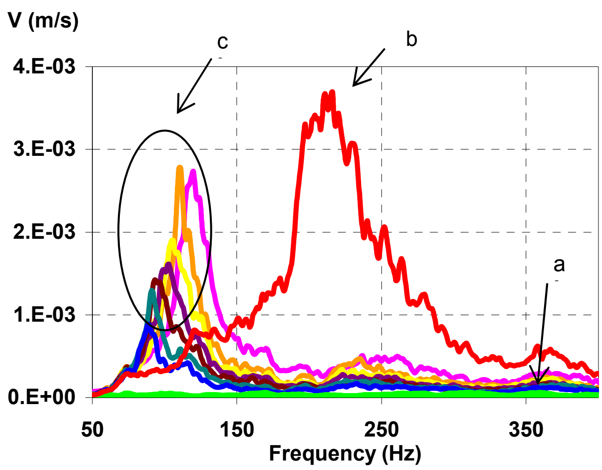


**Figure 3:** Influence of the thickness of the ground cover

## Influence of the nature of the ground

The same kind of experiment has been carried out in different soils with the mine buried under 4 cm of:

- sand,
- topsoil,
- pebbles + topsoil (measured on a pebble),
- grassy soil.

The results are almost the same for the resonance frequency as for the maximum amplitude (Figure 4).

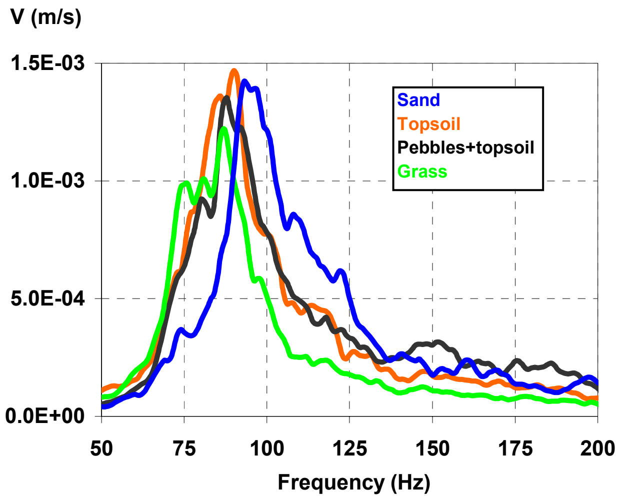


**Figure 4:** Influence of the nature of the ground

## Influence of the type of mine

The same kind of experiment is performed in order to verify if the type of mine has an influence. At this stage of the study we use real mines (emptied of their explosive), made of different materials (metal or plastic), with different dimensions, casing thicknesses, etc. Generally speaking, we have obtained good results for big antitank mines (AT) as well as for small antipersonnel ones (AP). For some mines we have observed two resonance frequencies (Figure 5). We can also notice that for one type of mine (monolithic exercise mine) a very small signal has been measured.

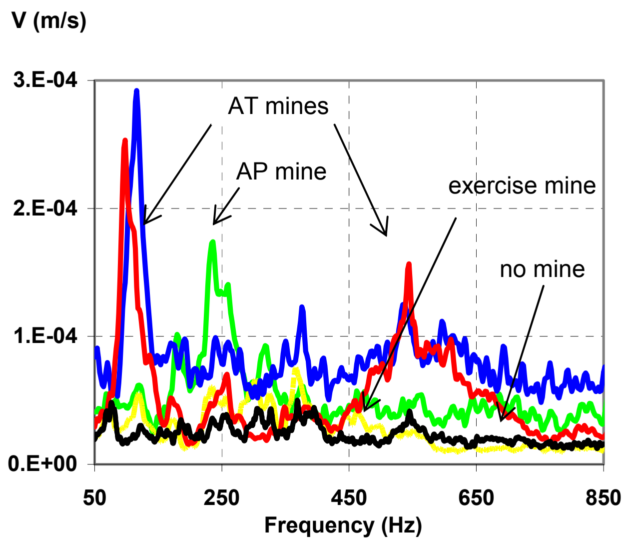


**Figure 5:** Influence of the type of mine

## Scanning measurements

In the previous experiments, the vibrometer was fixed and the points of measurement were static. To clear a portion of land it was necessary to scan the surface of the terrain. With this aim in view, we fixed the vibrometer on an x-y motorized rail table which was previously developed in order to test other mine detectors. In the course of this experiment we measured the vibration velocity of the ground during a straight displacement of +/- 1m of the detection head, centered on the mine. The result of this signal is visualized in the form of a spectrogram (but with a displacement scale for the x axis). The location of the mine is clearly visible (Figure 6). The main frequency is the same as during the static tests.

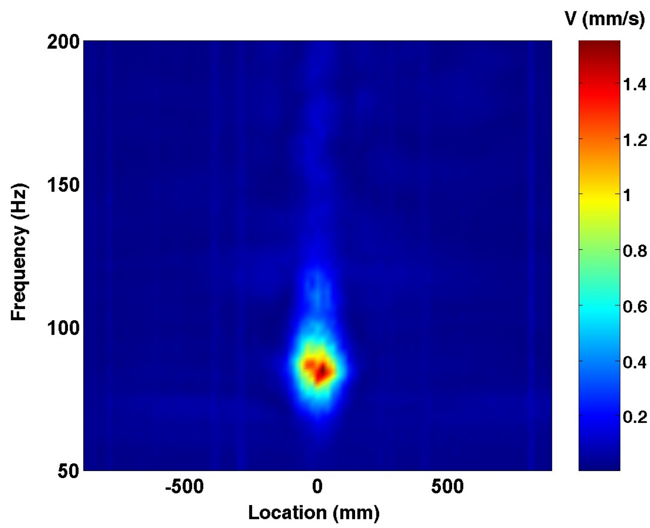


**Figure 6:** Visualization of the velocity spectrum during a scanning test

## Conclusion

This technique is very promising because it is non-invasive, and is complementary to metal detectors and infrared or radar methods. The first results show good capabilities of detection of:

- shallow-buried or on-surface landmines,
- mines of various sizes (AT or AP),
- metallic or plastic mines.

Future studies will try to optimize this method, for example by increasing the detection stand-off and by implementing faster scanning techniques.

## References


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