http://dx.doi.org/10.21611/qirt.2004.066

# Mine detection using the EMIR® method - Improved configuration using a mobile detection system

by Daniel Balageas, Michel Lemistre and Patrick Levesque

*° ONERA, Structure and Damage Mechanics Department, BP 72, 92322 Châtillon cedex, France*

**Abstract**

Traditional way of metallic mine detection by magnetic techniques are often efficient; however, many methods have been experimented in order to detect any kind of mine even those made in plastic with no convincing result. We propose to adapt to that issue the EMIR® method, already used in many other applications. Following preliminary results presented at QIRT 2002, a mobile detection system is evaluated leading to better images of buried mines or mine surrogates.

## 1. Introduction

If the classical magnetic techniques for mines detection can be considered as efficient, no technique is entirely satisfying for the detection of all types of mines, in particular for the mines fully made of plastic.

The EMIR® (ElectroMagnetic-InfraRed) technique, already used in various fields like NDE, electromagnetic compatibility, characterization of electromagnetic (EM) sources, etc… [1,2], has been proposed as an alternative to other techniques under development and some preliminary results presented at QIRT 2002 [3].

Improvement of the technique have been achieved, following two directions:

- improvement of the set-up configuration, in particular by optimizing the microwave illumination, replacing the single detector camera by a FPA camera, much more sensitive and with a better resolution, and by using a modulated EM field and a lock-in detection,
- use of sophisticated data reduction processes like wavelet transform analysis and Principal Component Analysis to facilitate the mine detection in the images.

The present paper, focused on the first type of improvements, describes the new configuration, presents typical mine and mine surrogate signatures, shows the influence of some physical and geometrical parameters on mine detectability. Enhancement by image processing will be out of the scope of this paper.

## 2. Principle of the EMIR® method and present measurement conditions

The EMIR® technique allows imaging EM fields, in particular in the microwave domain, thanks to an IR thermographic camera and to a photothermal converter (a conductive film). By the photon-heat process, the photothermal converter transforms the incident radiant energy into heat, and its temperature increase, detected by the camera, is directly proportional to the electric field intensity. The configuration adapted to mine detection was elaborated during preliminary tests [3]: the film is positioned parallel to the ground, which is illuminated by a 2.45 GHz source. The

http://dx.doi.org/10.21611/qirt.2004.066

visualized EM field results from the combination of the incident and reflected/ diffracted EM fields. Figure 1 shows the configuration during the preliminary tests (without the Agema 882 LW camera) and Figure 2 the new configuration.

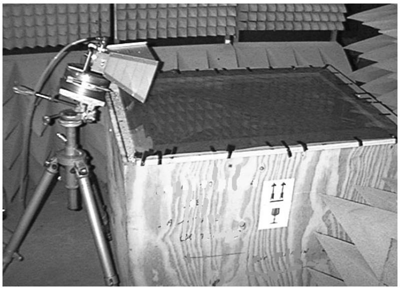

***Fig. 1.*** *Configuration of the preliminary tests, without the camera [3]*

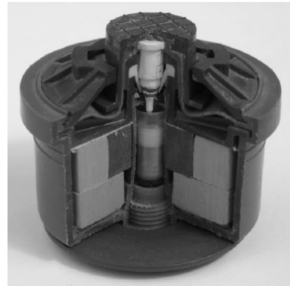

***Fig. 3.*** *Plastic mine with its metallic ring*

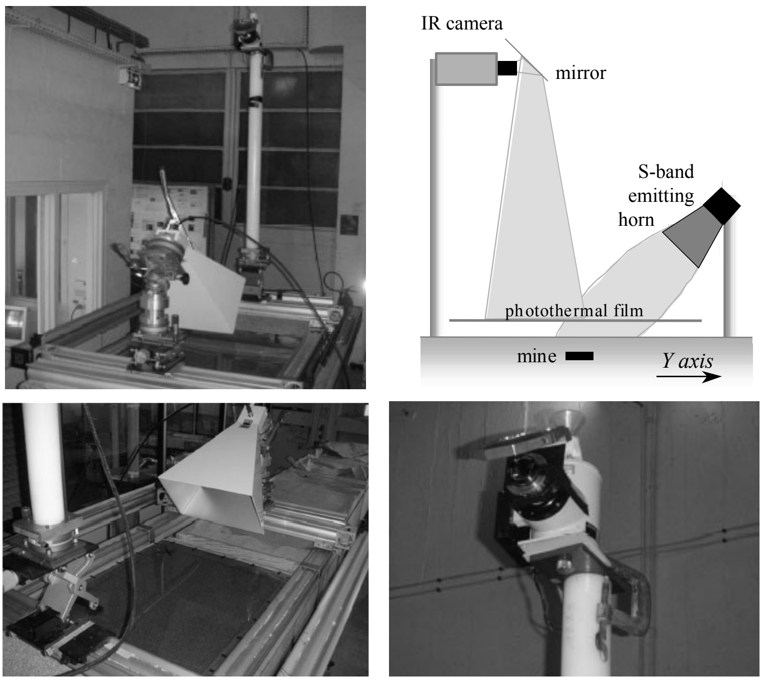


***Fig. 2.*** *Mobile EMIR® bench and test bed. Upper left: general view, upper right : configuration sketch, lower left: view of the illuminating horn and of the photothermal film, lower right: view of the Amber camera with the 45°-inclined mirror.*

For the preliminary tests [3], it was possible to use images of the ground (homogeneous sand inside the test bed) with and without mine. Such conditions are not representative of a real application, but, the aim was just to verify the validity of

http://dx.doi.org/10.21611/qirt.2004.066

the measurement principle. In practical application, the experimenter has no image of the ground taken before the mine insertion. He goes ahead with the detection system, coming from an area without mine towards an area where a mine is possibly buried. In such conditions, the detection must be possible even without reference image. To do this, both hardware and software improvements are needed.

The present tests are oriented towards the first solution, aiming, thanks to an optimized configuration of the EM source and of the IR camera, to produce images in which the pattern linked to the mine would not be drawn in the incident EM field as it was the case for the preliminary tests, with the correlative need to subtract the reference image (ground without mine). For this reason, the camera is viewing quasi vertically the ground thanks a mirror and the horn used is chosen to give a more uniform energy distribution than in the previous tests. The second improvement consists in using a lock-in thermographic system which suppress erratic temperature variations linked to the environment. Such choices need a more sensitive detection system. An Amber 4128 FPA camera is used giving a better thermal resolution (NETD $\leq$10 mK) and a better space resolution (128x128 pixels). A lock-in thermographic system working in post-processing mode, made at ONERA [1] can be used. The detection has been made in both amplitude modulation mode (1 Hz) and in CW illumination.

The only present limitation is due to the memory board associated with the camera, which just allows storing 492 images. As shown in [4], the lock-in system in EMIR application would need at least the accumulation of 10,000 images to give a really satisfactory sensitivity. In the near future the present system will be replaced by a CEDIP JADE camera with a real time lock-in system, as used in [4].

To permit a simulation of the real exploration process, the full system (emitting microwave source, photothermal film and camera) is held by a mobile bench moving upon a test bed simulating the ground (wood box with 50 cm of sand and buried mines) (see Fig. 2). A series of images is registered during the travelling of the mobile bench above the test bed. Each image is located by a reference distance between the mobile bench and the buried mine.

The buried objects used in these experiments are 50 mm-dia. metallic or plastic discs simulating mines, and also a real plastic mine (see Fig. 3), with or without a small metallic ring sometimes used in operational conditions when it is needed to recover the non exploded mine.

## 3. Parametric analysis

A series of tests has been first conducted with the more cooperative object: the metallic disc. The type of signatures generated by the buried object and the respective influences of the location depth and the inclination have been studied.

### 3.1. Mine surrogate signature

Figure 4 presents the signature of the metallic disc buried at 50 mm under the surface. The signature results from the interferences created by the incident EM field with the fields reflected and diffracted by the ground and by the object. The diffraction pattern is constituted by a main lobe and circular rings. Due to the inclination of the horn, the pattern is not axisymmetrical. CW and modulated illuminations gives similar results. This can be compared to the image obtained in CW regime during the preliminary tests (see Fig. 4 left). The fields of view are different in the two configurations: 300x775 mm in the preliminary tests and 300x300 in the present tests. The rectangular field of view of the preliminary tests is due to the inclination of the camera. In the present case the camera is viewing normally the ground surface,

http://dx.doi.org/10.21611/qirt.2004.066

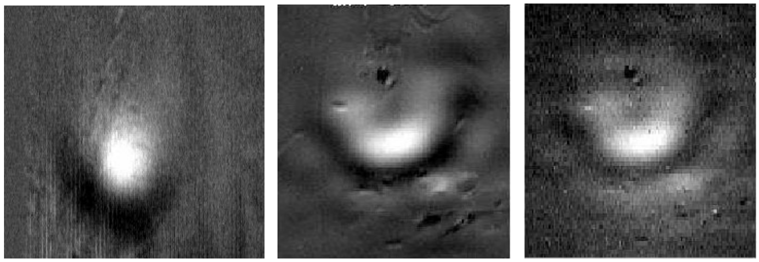

***Fig. 4.*** *Images of metallic discs at 50 mm under the ground surface. Left: CW image of a 60 mm-dia. disc resulting from a subtraction of the image of the ground without mine to the image of the ground with the mine (taken from ref. [3]); middle: CW image of a 50 mm dia. disc obtained during the present tests; right: image of the same disc obtained with lock-in detection (modulation frequency: 1 Hz).*

which does not introduce any distorsion. With the Agema camera the mine signature is not so regular and not so well-resolved as the one obtained with the Amber camera. Furthermore, a reference image (ground without mine) was needed, which is not the case presently. The lock-in image is more noisy than the CW image, due to the low number of accumulated images (492). The CW image needs the subtraction of the image taken before illumination to the image during illumination (mean image over 250 images). Local defects in these two images are due to defects in the mirror permitting the vertical viewing (the Amber camera has liquid-nitrogen dewar).

### 3.2. Influence of the in-depth location

Figure 5 presents the evolution of the metallic disc signature with location depths from 20 to 150 mm, for both CW and lock-in acquisitions. Signatures are similar. The lock-in images, more noisy, produces more regular patterns, and, in particular, the second ring is made more visible in the case of the higher depths. There are inversions in the maximum/minimum levels due to the variations of the phase difference between the field reflected by the ground surface and the field diffracted by the disc, variations which depend on the location depth. In effect, the range of explored depths is 150 mm, comparable to the EM wavelength (near 120 mm).

### 3.3. Influence of the mine inclination

Fig. 6 presents the influence of the inclination angle of the mine surrogate on its signature. Angle of ± 45° are tested, producing variations of the signature pattern. Nevertheless, even with so important angles, the structure of the signature is similar: a central lobe surrounded by rings. This must allow a relatively easy identification.

### 3.4. Signature of the plastic mine with a metallic ring

Figure 7 presents the signature of the plastic mine with its metallic ring. It is very similar to the disc signature. It is possible that the main contribution be due to the metallic ring. This is confirmed by the fact that, with the present system and contrarily to what was obtained during the preliminary tests, it was not possible to get a signature of the plastic mine without ring. The illumination field is now more uniform, but with the same global power, thus the maximum power density is lower. The enhancement of the signal-to-noise ratio given by a much higher number of accumulated images in the lock-in mode will solve this problem in the near future.

http://dx.doi.org/10.21611/qirt.2004.066

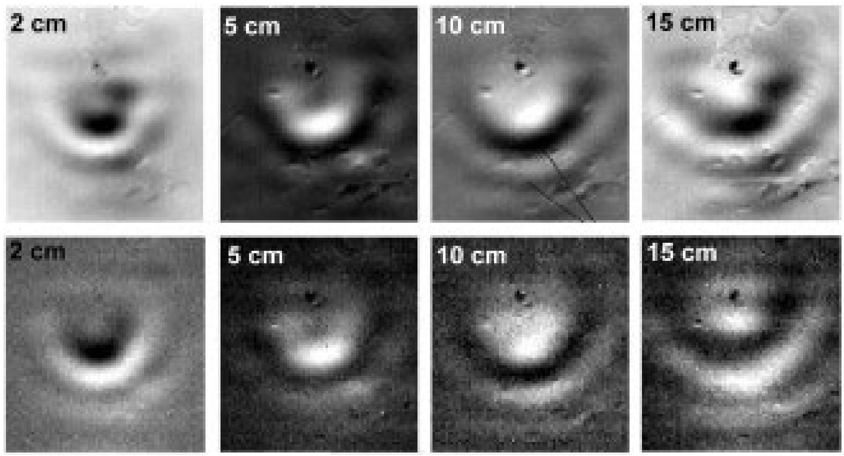


***Fig. 5.*** *Images of the metallic disc-shaped surrogate of mine corresponding to four different depths, with both CW (upper row) and lock-in detection (lower row).*

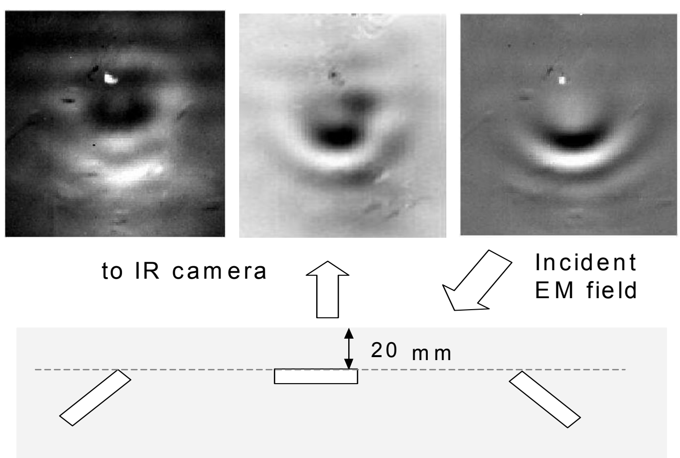


***Fig. 6.*** *Signature of the 50 mm.-dia. metallic disc with different tilt angles.*

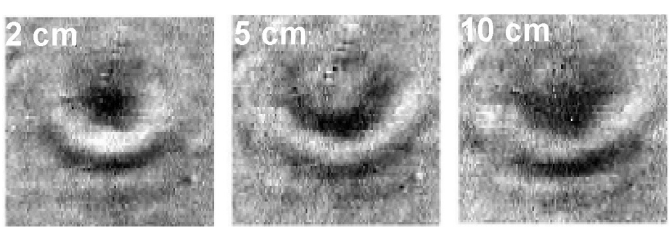


***Fig. 7.*** *Images of the real plastic mine with its metallic ring (see Fig. 3). Depths correspond the top of the mine.*

http://dx.doi.org/10.21611/qirt.2004.066

## 4. Simulation of the field procedure

To simulate the field procedure (full detection system moving ahead), a series of images consitituting a “movie” was taken, each image corresponding to a 50 mm-translation above the ground. Such a “movie” is presented in Figure 8, corresponding to the real plastic mine with its metallic ring, buried at 2 cm in an homogeneous sand. The images are obtained in the present case using CW detection and subtracting the mean image during illumination to the main image before illumination and making a min-max operation consisting to adjust the full scale of the image to the minimum and maximum levels in the raw image. In consequence, each image has is own scale and is not quantitatively comparable, but the process allow an easier qualitative detection and shape identification. Nevertheless, and partially due to this last image processing, these images are relatively complex. This is due to the presence of a space modulation like horizontal fringes due to the complicated very near-field of the source reflected by the ground. This pattern is really well visible only when the diffraction pattern due to the mine is at a low level, which occurs when the mine is not centered in the imaged field. The image processing envisaged (wavelet transforms and PCA) must help to discriminate the mine signature from this pattern (work in progress).

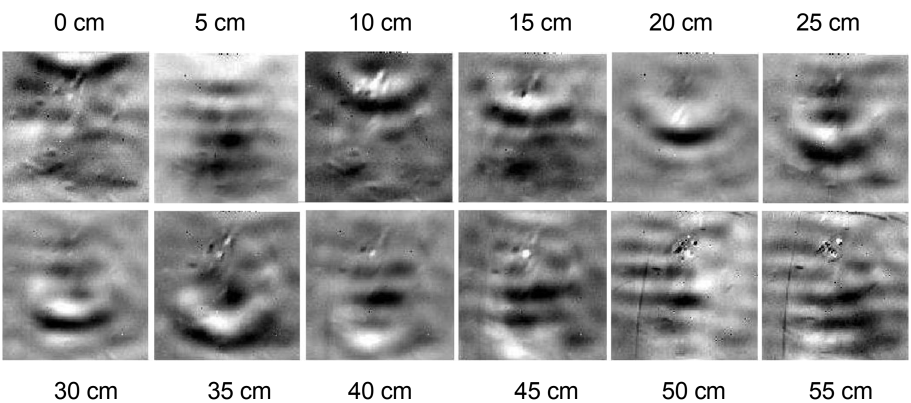


***Figure 8**. Raw “movie” corresponding to a plastic mine with a metallic ring, buried at 2 cm in sand. – Between each image the EMIR® detection system moves by 5 cm. The mine is moving from top to bottom of the image.*

## REFERENCES

[1] Balageas D., Levesque P., Déom A., " Characterization of electromagnetic fields using infrared thermographic systems", Proceedings SPIE, vol. 1933, 1993, p. 274-285.

[2] Balageas D., Levesque P., "EMIR a photothermal tool for electromagnetic phenomena characterization ", Revue Générale de Thermique, vol. 37, n° 9 (sept.), 1998, p. 725-739.

[3] Balageas D., Levesque P., " Mines detection using the EMIR® method ", Actes de la conférence QIRT 2002, Dubrovnik (Croatia), sept. 2002 , pp. 71-78, 2003.

[4] Levesque P., Brémond P., Lasserre J.-L., A. Paupert A., Balageas D.L., “Compared improvement by time, space and frequency data processing of the performances of IR cameras. Application to electromagnetism”, QIRT 2004.