Investigation of Holographic Radar Capabilities for the Detection of Shallow Buried Plastic Antipersonnel Landmines

Investigation of Holographic Radar Capabilities for the Detection of Shallow Buried Plastic Antipersonnel Landmines

T. Bechtel[1], **L. Capineri**[2], **P. Falorni**[2], **M. Inagaki**[3], **S. Ivashov**[4], **and C. Windsor**[5]

[1]Department of Earth and Environment, Franklin & Marshall College, Lancaster, PA, USA
[2]Department of Electronics and Communications, University of Florence, Florence 50139, Italy
[3]Walnut Ltd., 1-19-13, Saiwaicho, Tachikawa, Tokyo 190-0002, Japan
[4]Remote Sensing Laboratory, Bauman Moscow State Technical University, Moscow, Russia
[5]116, New Road, East Hagbourne, OX11 9LD, UK

Abstract— The RASCAN holographic subsurface radar [1] has been investigated for the detection of small plastic antipersonnel landmines buried at shallow depth in soil. The investigation consists of the comparison of data obtained by surface scans in an outdoor test bed with two RASCAN systems operating at different discrete frequencies near 2 GHz and 4 GHz, each with receiving antennae both parallel and perpendicular to the polarization of the transmitter. The two systems have different signal penetrations (up to 20 cm in dry soil for the 2 GHz), different antenna radiation patterns and different sensitivities for the parallel and perpendicular polarization images. RASCAN has the capability to record small phase changes in the received signals due to electromagnetic impedance discontinuities. This high sensitivity is an advantage to detect small (5 cm diameter) plastic targets but introduces also clutter signals due to surface irregularities and the other clutter objects commonly found in a battlefield. The choice of the operating frequency, the coupling of the antenna with the soil surface and the scanning spatial sampling is important to get enough information for the efficient detection of small plastic targets. Thanks to the high spatial resolution of the RASCAN images, the detection of targets by direct image interpretation is still possible, but is time consuming, is limited to the sensitivity of the human eye grey scale variations, and may be subjective based on different operators experience and level of expertise.

This paper is a comparison of the output of experiments made in Italy, Japan and USA using RASCAN holographic radar to identify the presence of plastic mine simulants buried in soil. Experiments covered the response variability due to surface conditions in Italian experiments, moisture level in Japan experiments and a feature of PMA-2 mines in USA experiments.

1. AIM OF THE EXPERIMENTS

Aim of these experiments is to study the effect of moisture, surface condition and target features on holographic radar response. In particular, experiments made in Japan considered the same target at different moisture levels, experiments made in USA considered the effect of the trigger on the detectability of a PMA-2 antipersonnel mine and experiments made in Italy considered different surface conditions in a outdoor setup.

The comparison is made against a elaboration algorithm [2] that considers response variations along spatial coordinate or along frequency coordinate. The algorithm take the output of RASCAN as input and produces two images, one based on frequency variations and the other based on spatial variations. Other than the classic geometric correlation (shape), targets can be identified on the two images by a normalized color scale: the higher is the value the higher is the probability of target response.

2. DESCRIPTION OF THE EXPERIMENTS

All experiments have been carried out by a joint team of researchers from Italy, USA and Japan. Each member of the team exploited a different facet of the general problem of buried mine simulants detection using RASCAN, from moisture effect on the background response to the constructional details of antipersonnel mines.

2.1. Experiments from Japan

In the first experiment two targets was buried in a sandbox at depths of about 3–4 cm and separated by 9 cm (see Figure 1). The aim of the experiments is to see which is the effect of different trigger type combined with different moisture level.

Measurements was performed with dry sandbox (humidity 0% of mass water) and wet sandbox (humidity 3% of mass water).

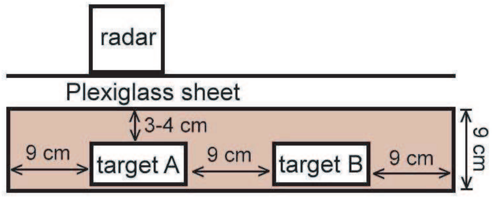
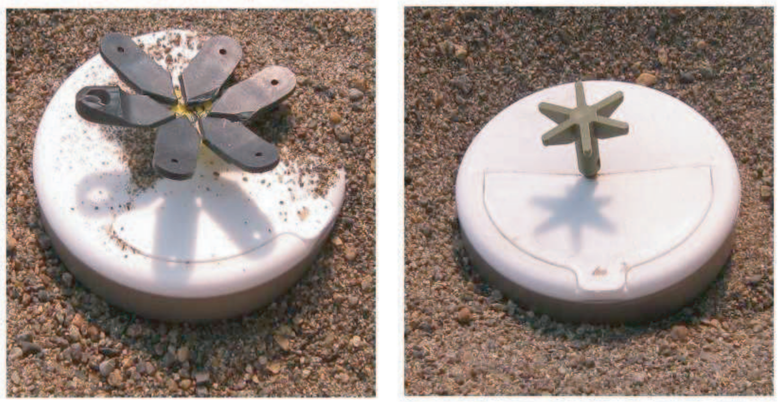
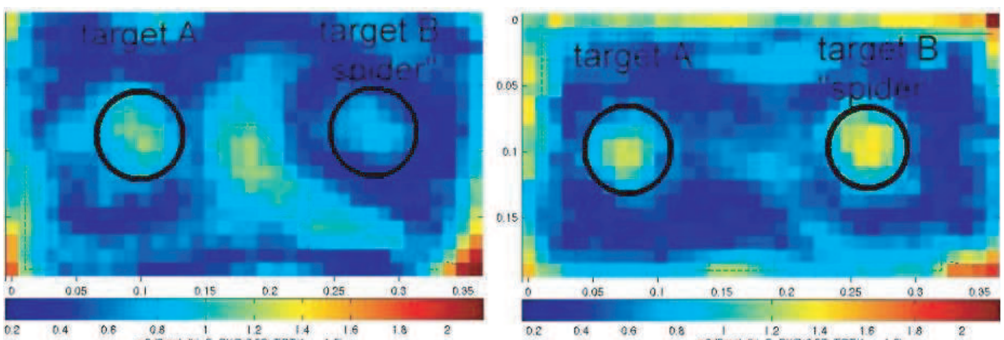


Figure 1: Layout of experiment from Japan.



(a) (b)

Figure 2: (a) Target A with big trigger, filled with granulated sugar (dielectric constant from 2.5 to 3.2). (b) Target B with small trigger.



(a) (b)

Figure 3: (a) Results for moisture level 3%. (b) Results for moisture level 0%.

Two cylindrical plastic boxes, one with big trigger and the other with small trigger, was used as targets (see Figure 2).

Results shows a little variation with spider type and a significant reduction in detectability when moisture level rise to 3% mass water.

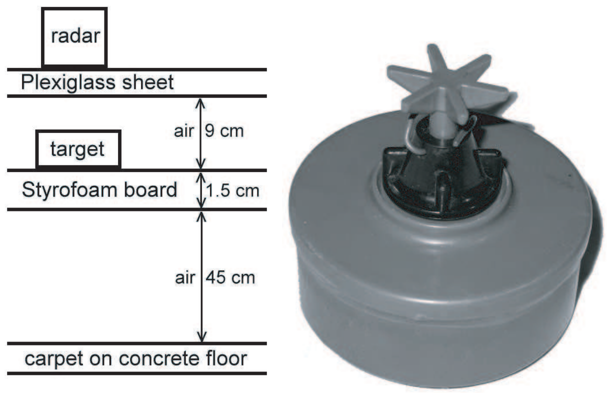
2.2. Experiments from the USA

In this experiment was tested the effect of the presence of the spider trigger above a small plastic antipersonnel mine named PMA-2. These scans were done in air to avoid soil effects.

One scan is with the trigger while the other is without the trigger. The mine body was not moved at all (see Figure 4 for the experiment layout).

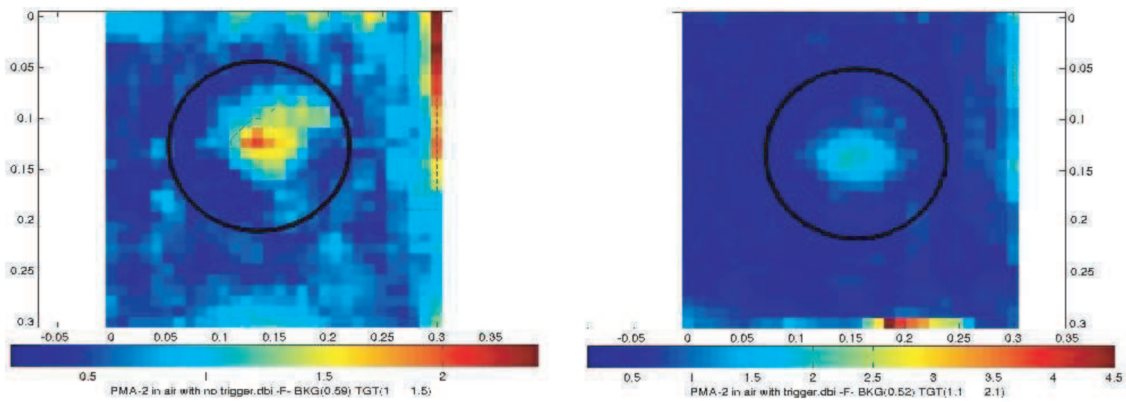
The target was a PMA-2 mine simulant filled with granulated sugar (dielectric constant 2.9). Size of the simulant is 61 mm height by 68 mm diameter (see).

Results in Figure 5 show little variations between the two tests with or without trigger. Notice that the two images don't have the same color scale but from the color bar it can be seen that the two target areas share about the same values.



(a) (b)

Figure 4: (a) Layout of experiment from USA. (b) View of the PMA-2 mine simulant.



(a) (b)

Figure 5: (a) Results with no trigger. (b) Results with trigger.

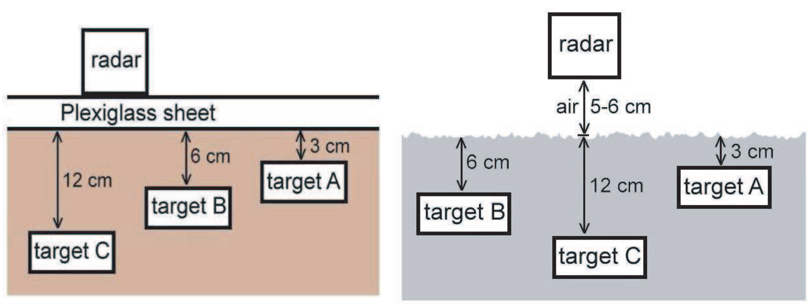


Figure 6: Section view of the layout of Italian experiment.

2.3. Experiments from Italy

In these experiments it was tested the effect a real outdoor environment, with vegetation and uneven surface and soil composition. The test field is a squared area of about 3 m side where test objects are buried from long time (about two years).

One corner of the area is reserved for new tests and has been excavated to perform these tests. In the first test scanning was performed coupling the antenna with the ground by using a plexyglass sheet while the second test was performed by scanning with a air gap of about 5–6 cm (see Figure 6 for details).

The three targets are circular boxes (radius $R = 6$ cm, thickness $H = 3$ cm) filled with epoxy (dielectric constant from 2.9 to 3.7) and buried on a straight line at various depths (see Figure 6 for details). Results in Figure 7 show that the air gap significantly reduce the detectability of targets in a outdoor field test environment.

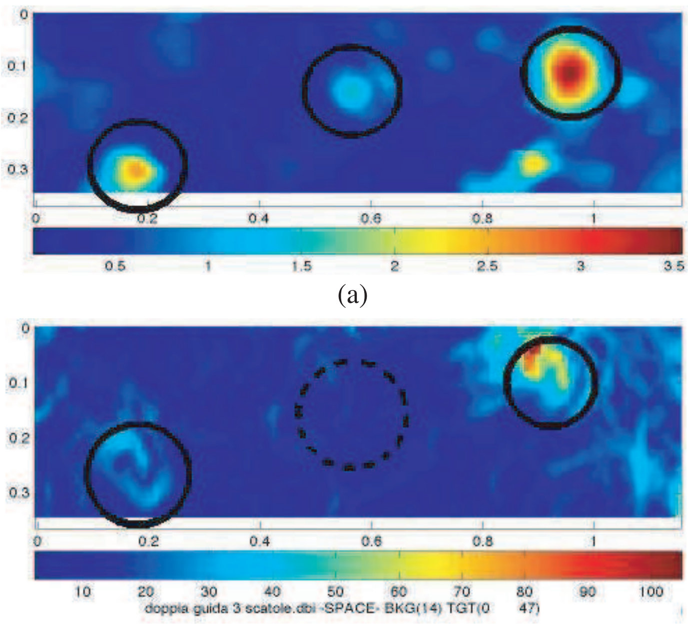


Figure 7: (a) Scanning in contact with ground. (b) Scanning with air gap. (Left) target C, (Middle) target B, (Right) target A.

3. ELABORATION ALGORITHM

All comparisons have been carried out by using an algorithm that takes all ten RASCAN images (two polarizations by five frequencies) and produces a single image based on image variations with respect to HSR frequency. The algorithm normalize each single image (identified by polarization and frequency) subtracting mean value and dividing by standard deviation. After this phase, for each polarization, the standard deviation along frequency dimension is evaluated. Finally the two images are square-summated and the resulting image is normalized. The rationale of this calculation is that a target will have a frequency response that is more complicated with respect to the background.

Values in the final image can be subdivided into two parts: one (background) made by values that are close to their mean value and the other (target) made by highly scattered values.

4. CONCLUSIONS

An algorithm that apply variations of received signal along frequency abscissa has been developed and used as a comparison mean.

Experiments from Japan and Italy showed that moisture level highly influence the detectability of buried objects because it tends to create a confused (foggy) background.

Experiments from the USA and Japan show that the detectability of a PMA-2 antipersonnel mine in air is quasi independent on the presence and type of trigger.

Experiments from Italy showed that there can be the case where the same object in the same medium can be better detected at higher depths.

ACKNOWLEDGMENT

The authors wish to acknowledge the contribution of Francesco Fiesoli for the organization of the experimental tests in Italy.

REFERENCES

1. Ivashov, S., V. V. Razevig, I. A. Vasiliev, A. V. Zhuravlev, T. D. Bechtel, and L. Capineri, "Holographic subsurface radar of RASCAN type: Development and applications," *IEEE Journal of Selected Topics in Earth Observations and Remote Sensing*, Accepted on June 5, In Print Digital Object Identifier JSTARS-2010-00097, 2011.
2. Windsor, C. G., A. Bulletti, L. Capineri, P. Falorni, S. Valenini, G. Borgioli, M. Inagaki, T. D. Bechtel, E. Bechtel, A. V. Zhuravlev, and S. I. Ivashov, "A single displays for RASCAN 5-frequency 2-polarisation holographic radar scans," *PIERS Online*, Vol. 5, No. 5, 496–500, 2009.