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A STEP-WISE MICROWAVE IMAGING STRATEGY FOR LANDMINE DETECTION
MODELLING AND NUMERICAL ASSESSMENT

A. Brancaccio(1,7), G. Maiello(1,7), M.D. Migliore(2,7), D. Pinchera(2,7), F. Schettino(2,7), T. Isernia(3,7), M. Ambrosanio(4,7),V. Pascazio(4,7), L. Di Donato(5,7), L. Crocco(6,7)

(1) DIII, Seconda Università di Napoli
(2) DIEI, Univ. di Cassino e del Lazio Meridionale
(3) DIIES, Univ. Mediterranea di Reggio Calabria
(4) Dipartimento di Ingegneria, Univ. di Napoli Parthenope
(5) DIEEI, Università di Catania, Catania
(6) IREA-CNR, Napoli
(7) CNIT
(8) adriana.brancaccio@unina2.it

Abstract
The problem of mine detection by means of electromagnetic waves is dealt with. The paper summarizes the authors' contribution to the European project D-Box. Three complementary techniques for data processing in a short range detection configuration are presented and applied to a common numerical test-bed.
Index Terms – antenna, compressive sensing, electromagnetic inverse scattering, mine detection.

I. INTRODUCTION

A complete step-wise Microwave Imaging Strategy for landmine detection and characterization has been proposed and tested in both numerical and experimental scenarios. The proposed novel approach is based on a succession of three different steps, which increases the useful information on the unknown buried objects by means of step-wise refinements. More in detail, the different "levels" of the processing are: localization of the target in the scan plane; in-depth target localization and shape imaging; "quantitative" characterization of the unknown objects, defining their nature and classification (i.e., rock, mine, plastic objects, etc.).
The whole processing takes advantage of the useful independent information coming from frequency diversity.
Before moving towards the experimental case, the proposed methodology has been tested in a controlled, numerical environment in order to assess its retrieving performance. The numerical test-bed consisted of a multiview-multistatic configuration with a horn antenna (16.7 dBi gain) with both Anti Personal (AP) and Anti Tank (AT) like mine phantoms.

Such a validation has been carried out for dielectric as well as metallic mines.

II. NUMERICAL RESULTS

The soil is modelled by a 2.5m×2.5m×1m box having relative permittivity 4 and conductivity 0.01 S/m, embedded in a 3.3m×3.3m×1.3m box of absorbing material having the same relative permittivity 4 and conductivity 0.1 S/m. Source is a horn antenna (16.7 dBi gain), placed at two meters above and rotated by 30 degrees toward the soil as shown in Fig. 1. The three rectangular components of the field are evaluated at soil-air interface over a uniform grid along x and y having 50 mm step. Data are simulated at three frequencies: 0.9 GHz, 1.0 GHz and 1.17 GHz, and for different positions of the transmitting antenna along the soil box perimeter. Mines are modelled by circular cylinders buried at 50 mm from the surface of the soil: metallic AT mine radius 100 mm, height 100 mm, material PEC (perfect electric conductor); dielectric AP mine radius 50 mm, height 50 mm, relative permittivity of the material equal to 2.7.
In order to obtain the scattered field, measurements in absence of mines have been simulated and subtracted to those calculated in presence of mines.

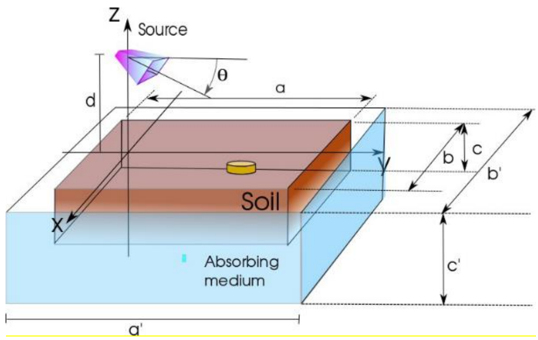

FIG. 1 – Numerical test-bed employed in the numerical assessment**.**

First step: localization of the target in the scan plane has been carried out by exploiting an equivalent-surface-current approach. The scattered field caused by an external single frequency electromagnetic source is seen as the field radiated by equivalent surface electric currents located over a plane at a depth smaller than the scatterers' one. The support of such equivalent currents is assumed as the unknown of the inverse problem. In this way the mathematical relationship between data (the scattered field) and unknown (the equivalent surface current) is linear where its kernel depends on either far or near field measurement conditions occur. It has to be stressed that the model does not require knowledge of the incident field, except for its frequency. The inversion result is a 2D image representing the reconstructed current, whose support indicates presence and position of scattering objects (mines). The output of the first step is a two-dimensional map of the position of the support of the objects "projected" on the surface plane (Fig. 2).

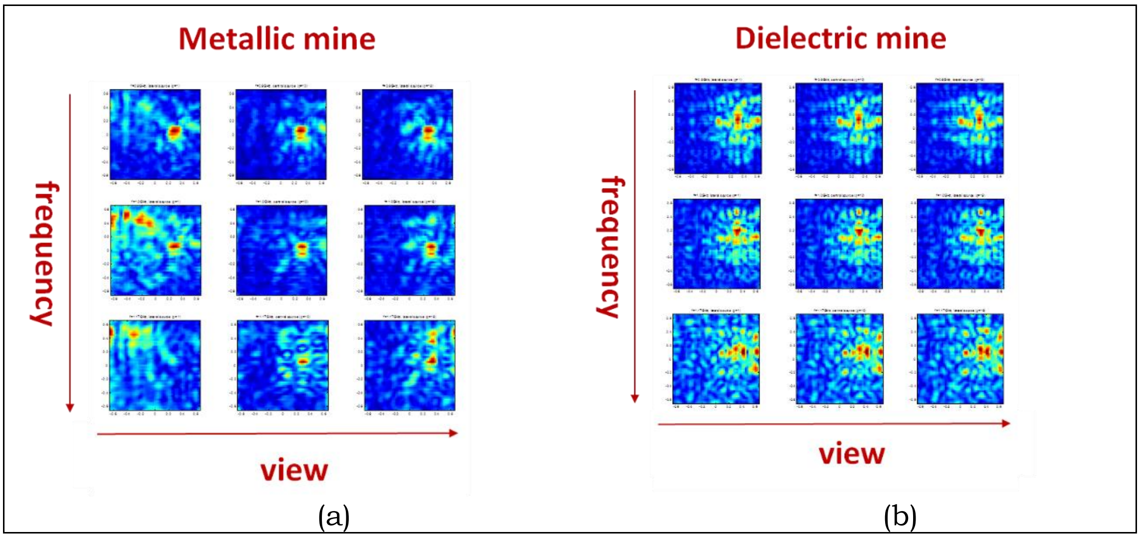

FIG. 2 – First-step recoveries for metallic (a) and dielectric (b) mines

Second step: in-depth target localization and shape imaging has the aim of improving the information on the detected objects providing approximately their shape and in-depth location. It performs single-frequency recoveries by exploiting the Linear Sampling Method (LSM), as shown in Fig. 3.

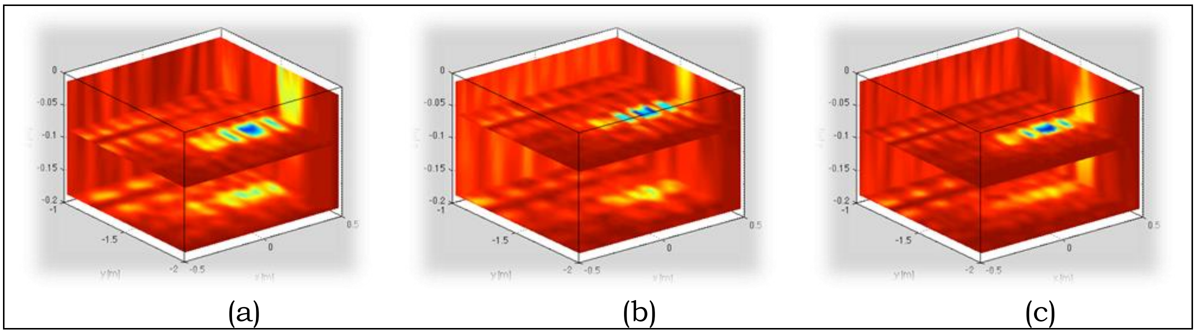

FIG. 3 – Second-step single-frequency recoveries by exploiting LSM:
(a) 900 MHz, (b) 1 GHz and (c) 1.17 GHz.
(b)

Third step: quantitative characterization of buried targets thanks to the reduction of the imaging area, this last step uses a hybrid strategy which exploits the compressive sensing (CS) theory and the quantitative "virtual experiments" (VE) framework [3].

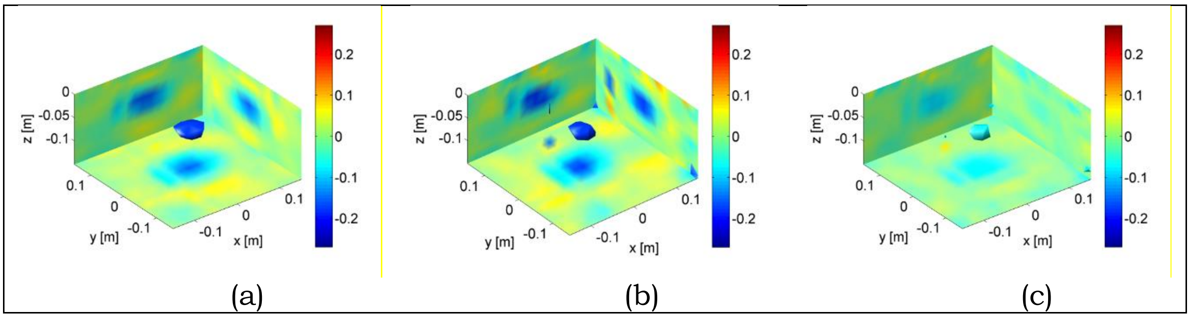

FIG. 4 – Third-step single-frequency single-component scattered field recoveries by exploiting CS: (a) x-component, (b) y-component and (c) z-component.

III. CONCLUSIONS

The proposed strategy manages in retrieving both the shape and locations of buried unknown objects quite well, as proved in the numerical analysis. Some advantages of the proposed methodologies are related to retrieving qualitative information on targets location (i.e., shape), reducing the number of measurements compared to standard tomographic approaches and no need of expert user to understand the retrieved maps. After the numerical validation, the processing has been tested preliminarily in a laboratory-controlled situation [1] and then directly on a sandy soil. During the experimental campaign, both horn antenna and a home-made ultra-wide-permittivity antennas (UWPA) have been tested [2]. Such experimental validation is in progress and will be shown at the Conference.

ACKNOWLEDGEMENT

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