Landmine Detection Using Electromagnetic Time Reversal Based Methods

Hamidreza Karami[1], André Koch[2], Carlos Romero[2], Marcos Rubinstein[3], Farhad Rachidi[1]
[1] EPFL, Lausanne, Switzerland, hamidreza.karami@epfl.ch and farhad.rachidi@epfl.ch
[2] armasuisse Science and Technology, Thun, Switzerland, andre.koch@DynamicPhenomena.ch and carlos.romero@ar.admin.ch
[3] University of Applied Science of Western Switzerland, Yverdon-les-Bains, Switzerland, marcos.rubinstein@heig-vd.ch

***Abstract*—**In this paper, the interaction between a measurement system, the landmine, and the soil is investigated to detect an unknown buried object. In particular, the performance of different approaches for landmine localization using electromagnetic time reversal (EMTR) methods is investigated in terms of their detection efficiency and computational efficiency. The considered methods include the classical time-domain EMTR, iterative EMTR, EMTR-DORT (decomposition of the time reversal operator), and EMTR-MUSIC (Multiple signal classification). The obtained simulation results show that EMTR is a promising technique for landmine detection and localization.

Keywords- Landmines; time reversal base methods;

I. Introduction

Although a large spectrum of methods has been investigated to detect landmines, only enhanced metal detectors and ground penetrating radars have been used in the field [1]. The performance of these methods is still far from the desired levels due to the complexity of the environmental and field conditions. In this paper, time reversal methods in both the acoustic and the electromagnetic regime [2] have been applied to localize landmine(s). We present the results of an investigation in which different types of EMTR based methods (classical EMTR, iterative EMTR, DORT, and TR-MUSIC) are applied to the problem of landmine localization. These methods have shown to be promising in terms of accuracy and efficiency in localizing landmines, and could potentially replace or complement existing methods in the future.

II. Comparison between EMTR-Based Methods

The simulation results showed that both the TR-MUSIC and DORT methods, implemented in a single frequency, were able to accurately locate the targets. The resolution of the DORT method can be increased by increasing the number of antennas. However, even with a higher number of antennas, DORT does not allow to achieve super-resolution. With a similar computational cost to that of the DORT method, EMTR-MUSIC is able to achieve super-resolution to distinguish targets located within distances as low as $\lambda/20$. The classical EMTR method implemented in the time-domain requires higher computational resources compared to DORT and TR-MUSIC.

In summary, TR-MUSIC appears to outperform other EMTR-based methods, allowing to detect multiple closely spaced targets using a reasonable number of sensors.

III. Numerical Results

As seen in Figure 1 (a), A 5-mm radius spherical metallic target is buried in a homogeneous soil at a depth d = 0.4 m. Three identical dipole antennas are used as transmitters with length and radius 135.5 mm and 2.5 mm, respectively. At 1 GHz, the antenna return loss is about 20 dB, which is appropriate to detect landmines at this frequency. All dipole antennas are at a height h = 0.5 m above the ground. The horizontal distance between adjacent antennas is s = 0.5 m. The frequency range of the excitation Gaussian pulse is from 0 to 2.0 GHz.

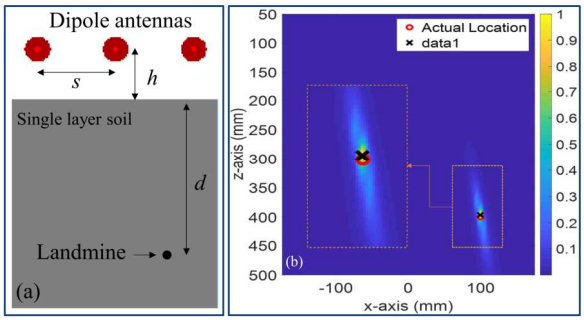

Figure 1. (a) A view of the geometry of the homogenous soil half-space problem. (b) 2D view of the TR-MUSIC pseudospectrum. The red circle and the black cross show the actual and estimated landmine locations. The soil permittivity and conductivity are 4.0 and 0.01 S/m, respectively.

Figure 1(b) shows the TR-MUSIC pseudospectrum obtained using the CST-MWS time-domain solver. The red circle and black cross show respectively the actual and estimated target locations. In this case, TR-MUSIC could localize the landmine with a localization error of 3.58 mm.

REFERENCES

[1] "Guidebook on Detection Technologies and Systems for Humanitarian Demining | Geneva International Centre for Humanitarian Demining." [Online]. Available: https://www.gichd.org/en/resources/publications/detail/publication/guidebook-on-detection-technologies-and-systems-for-humanitarian-demining/. [Accessed: 21-Jan-2021].
[2] V. R. N. Santos and F. L. Teixeira, "Application of time-reversal-based processing techniques to enhance detection of GPR targets," J. Appl. Geophys., vol. 146, pp. 80–94, Nov. 2017.