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# Ground Penetrating Radar Data Imaging via Kirchhoff Migration Method

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***Abstract*—In this paper the imaging of Ground Penetrating Radar (GPR) scenario via Kirchhoff migration (KM) method is seen as a validation of the controlled experimental data and as a first step toward more elaborate imaging techniques. One of our goals is to have the possibility to acquire experimental data in a controlled laboratory environment. The bi-static GPR data is then acquired and validated by comparison with electromagnetic simulation. The imaging process is obtained using either the total field or the filtered one.**

***Index Terms*—GPR, imaging, Kirchhoff migration.**

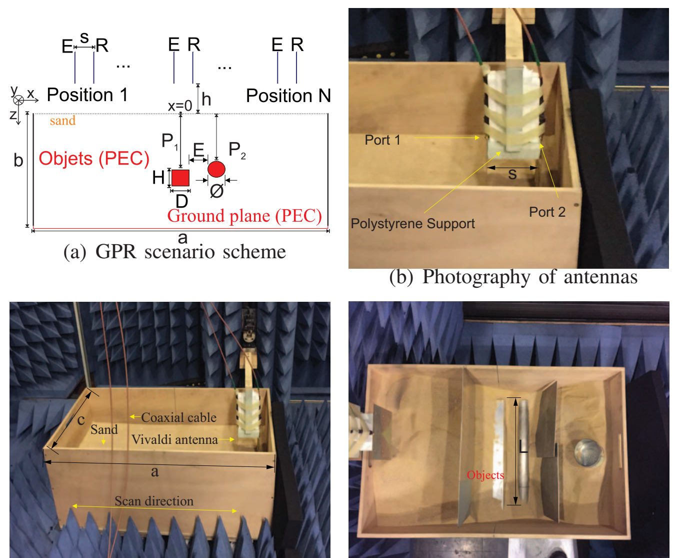
## I. Introduction

The use of Ground-Penetrating Radar (GPR) has been developed in an extended number of applications for many years. The GPR technique is used in geophysics and civil engineering to provide effective and accurate imaging of underground structures and for buried objects detection. It still needs development as shown by the recent COST Action TU1208 “Civil Engineering Application of Ground Penetrating Radar” [1], [2], [3]. Therefore, it is interesting to explore the GPR performance for estimating the target location.

The migration techniques are the traditional GPR imaging tools enabling to localize the targets with relatively high-resolution [4], [5], [6]. The Kirchhoff migration is applied onto the B-scan GPR data obtained either using the measurements in the CentraleSupélec anechoic chamber or the synthetic data computed by the electromagnetic simulation software CST MICROWAVE STUDIO (CST-MWS). The other migration techniques (Stolt, Stripmap, SAR) are equivalent to Kirchhoff one. We have chosen this technique because of its simplicity and reliability for GPR data analysis.

## II. GPR scenario

The front view scheme of GPR scenario is presented in Fig. 1(a), where E/R denote the transmission/reception Vivaldi antennas operating from $500\,\mathrm{MHz}$ to $3.5\,\mathrm{GHz}$ with 128 frequency-steps. The wooden box filled with dry sand ($\epsilon_r \simeq 2.53$) is placed over a metal plate in order to eliminate uncontrollable reflections below the box. Two metal bars of the same length and of square/circular cross-section are buried in the sand. The center of the sandbox is considered as the origin of the axis, the B-scan displacement range going from $-200\,\mathrm{mm}$ to $200\,\mathrm{mm}$ with a step of $20\,\mathrm{mm}$. More details of the GPR scenario parameters can be found in Fig. 1. The

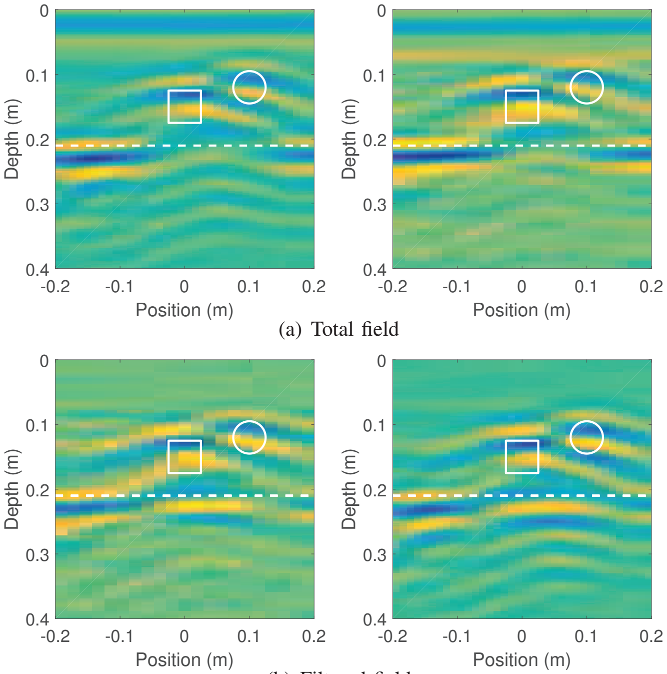



(a) GPR scenario scheme
(b) Photography of antennas
(c) Measurement system
(d) Buried targets

Fig. 1. GPR scenario scheme (a), the dimensions (in mm) being $a = 1000$, $b = 210$, $c = 600$, $H = 50$, $D = 50$, $L = 500$, $P_1 = 125$, $\varnothing = 50$, $P_2 = 95$, $E = 50$, $S = 100$, $h = 2$ and photos of the equipment (b) (c) (d).

same configuration is considered in the simulation procedure with CST-MWS in which both the antennas and sandbox are modeled (3D model). Comparison between experimental data and synthetic data (either computed using CST-MWS or using a laboratory-made software based on Discontinuous Galerkin Time-Domain method) are shown in [7].

The experimental and synthetic radargrams are presented in Fig. 2. The total field radargram (Fig 2(a)) includes the reflections due to the air/sand interface, the antennas coupling, then, the buried metallic objects and finally, the bottom metal plate placed under the sandbox. The reflections due to the air/sand interface and antennas coupling can be seen as a perturbation and should, when possible, be eliminated. One way to do it is to have access to the incident field defined as the electromagnetic field existing in the absence of the targets and to subtract it from the total field to be able to work with the scattered field. However, in the practical GPR case, the measurement of incident field is usually unavailable and could be replaced by the average of the total field on the receivers leading to the filtered field. The latter, shown in Fig 2(b),




(a) Total field

(b) Filtered field

Fig. 2. Radargrams with two buried objects: CST-MWS (left) and measurement (right), the solid line contour present the exact position of buried objects, the dashed line is the bottom metal plate.

is similar to the scattered one. A good agreement between simulation and experimentation is obtained for all the fields.

## III. GPR imaging results via Kirchhoff migration

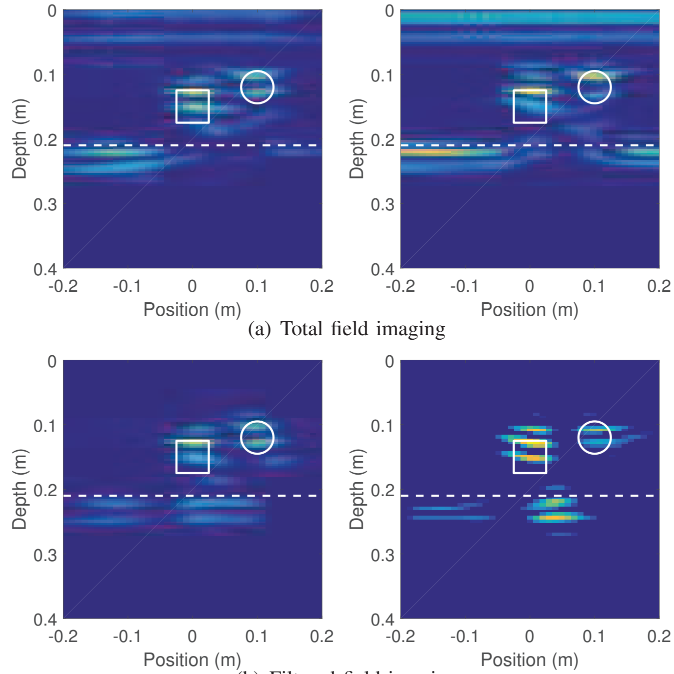
As shown in the radargrams, the scatterers are delineated by hyperbola signatures. In this section, the KM imaging technique is applied to attempt to localize the targets with a higher resolution.

KM is based on an integral solution of the scalar wave equation. It is performed by using the Kirchhoff integral representation of a field at a given point as a superposition of waves propagating from adjacent points and times [8]. Our KM imaging results are displayed in Fig. 3. As expected the focusing onto the targets and the metal bottom plate locations is achieved by applying the KM either onto the measured data or the simulated one. The results using the filtered field (Fig. 3(b)) show an improvement of the localization by washing out the air/sand interface reflections and the antennas coupling.

## IV. Conclusion

In this paper, the synthetic and measured B-scan GPR data are used for GPR imaging via Kirchhoff migration. Localization of two obstacles has been achieved. A filtering process is used to eliminate the environment influences while the incident field is absent. More detailed informations and results will be discussed during the conference.

As well-known the Kirchhoff migration does not provide any information about target shape and/or extension and should be seen as a first step toward more advanced imaging techniques such as an Enhanced Linear Sampling Method already developed by the authors in a free space configuration [9] and currently under extension for the GPR application.




(a) Total field imaging

(b) Filtered field imaging

Fig. 3. KM imaging : CST-MWS (left) and measurement (right).

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