# Imaging Comparison of GPR Based on Multi- and Bi-static Configurations

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**Abstract.** In this paper, a comparison of two ground penetrating radar (GPR) systems is presented, the classical bi-static one and the Multiple Input Multiple Output (MIMO) system both using $N$ Vivaldi antennas. For both configurations a Linear Sampling Metthod (LSM) imaging algorithm and Kirchhoff migration technique are used for target detection and localization. The performance of both systems are compared through a parametric study based on synthetic data modeling a GPR scene.

**Keywords.** Ground Penetrating Radar, Kirchhoff Migration, Linear Sampling Method, MIMO Radar, UWB antenna

## 1. Introduction

GPR is a non-invasive detection tool used in geophysics and civil engineering to provide effective imaging of underground structures [1,2]. As an extension of the antenna optimization dedicated to GPR, we are interested in combining wide band antennas to get a multiple input multiple output (MIMO) radar system. Exploiting the diversity of information provided by a MIMO system improve the reconstruction of buried objects.

In this paper, we aim at comparing the imaging results using two B-scan data using two GPR systems. In the first case, a quasi mono-static radar composed of two Vivaldi antennas to sweep a line above the 2D buried targets whereas, in the second one, we use an array of Vivaldi antennas to scan along the same line as for the mono-static configuration while activating sequentially transmitting and receiving antennas (MIMO system). The B-scan data resulting from the mono-static radar are processed using the Kirchhoff migration technique [3]. In the multi-static case, we use the LSM [4] for the data processing. We aim at studying the relevance of using multi-static radars for detection quality enhancement.

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## 2. Kirchhoff Migration and Linear Sampling Method for data imaging

We have chosen the Kirchhoff Migration (KM) method due to its popularity in the GPR community. It is used for B-scan radargram as a focusing technique for buried target localization. The KM is based on an integral solution of the scalar wave equation. The LSM technique can reconstruct the geometrical features of both dielectric and metallic targets from multi-static measurement configuration.

A 2D example with two buried targets is considered. They are placed into an infinite sand box and $N$ transmitting and receiving Vivaldi antennas are used to generate the multi-static matrix needed for LSM technique and the B-scan used for the KM migration. The sand dielectric properties are similar to those of a dry sand. Respecting this configuration, a parametric study is carried out to illustrate the feasibility and reliability of LSM for GPR application. The LSM results are compared with KM technique as a function of targets dielectric properties, the measurement extension $L$, the distance between buried targets (mutual coupling between targets). The synthetic multi-frequency and multi-static data are obtained using the CST full wave simulation software and the antenna $S$ parameters are used in the imaging.

## 3. Conclusion

In this paper, we aim at comparing the usefulness of data extension brought by MIMO GPR systems combined with the efficiency for LSM techniques. The imaging results are compared for LSM and KM techniques for a realistic situation taking into account the antenna radiation pattern and the coupling between the antenna and the soil comprising the scattering targets. We have studied the operating limits of the Kirchhoff migration technique for several configurations using different numbers of transmitting and receiving antennas, spacing between them, and operation frequencies. The results of 2D scattering targets can be generalized to 3D case.

## References


[1] A. Aboudourib, M. Serhir, and D. Lesselier, "A processing framework for tree-root reconstruction using ground-penetrating radar under heterogeneous soil conditions," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 59, no. 1, pp. 208–219, 2021.

[2] X. Liu, M. Serhir, and M. Lambert, "Detectability of junctions of underground electrical cables with a ground penetrating radar: Electromagnetic simulation and experimental measurements," *Construction and Building Materials*, vol. 158, pp. 1099–1110, 2018.

[3] J. Gazdag and P. Sguazzero, "Migration of seismic data," *Proc. IEEE*, vol. 72, no. 10, pp. 1302–1315, 1984.

[4] L. Crocco, L. Di Donato, I. Catapano, and T. Isernia, "An improved simple method for imaging the shape of complex targets," *IEEE Trans. Antennas Propagat.*, vol. 61, no. 2, pp. 843–851, 2013.