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# VALIDATION OF GROUND PENETRATING RADAR DATA INTERPRETATION USING AN ELECTROMAGNETIC WAVE PROPAGATION SIMULATOR

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*Abstract*. This paper is divided in two parts, in the first part is presented a method of validating radargrams interpretation, using matGPR model builder and simulator. The second part demonstrates the applicability of this method with simulations based on several radargrams obtained from GPR investigations made in Romania.

*Key words:* model, radargram, split-step method.

## 1. INTRODUCTION

The ground penetrating radar (GPR) is a geophysical, non-invasive, method of investigating the ground by emitting and studying the propagation of electromagnetic pulses. The radiation used is from the microwave spectrum, which is reflected due to the discontinuity of dielectric materials, discontinuities that can represent buried objects / structures or stratigraphy differences. The possibility of buried material identification, regardless of their nature, makes this technique applicable in various fields, including archeology, complementing the traditional prospecting techniques.

The amplitude of the reflected signal along with the duration of propagation are recorded by the equipment, and can be viewed as a curve referred in the literature as trace (A scan). By moving the equipment across the soil in one direction, adjacent traces are obtained that form an image, known as radargram (B scan). As it happens in the case of using other investigation techniques, to develop a complete GPR report three stages are required, respectively acquisition, processing and data interpretation. After the acquisition the next step is processing the data, operation done using dedicated software that provide filters and algorithms used for removing DC component, background noise, or narrowing the frequency band, with the purpose of keeping only the information of interest from records.

The interpretation is the most complex part, requiring knowledge about the: propagation of electromagnetic radiation, archaeology, soil proprieties, etc. In order for interpretations to be as accurate as possible, simulators for the propagation of electromagnetic radiation can be used, that allow the creation of complex shapes and physical properties environments (setting the relative dielectric permittivity, resistivity, magnetic permeability), but also choosing an antenna with the frequency equal to that used in situ investigations. By comparing the simulation results with the radargrams can be: improved the data interpretation, minimized the errors and even predict how buried remains in archaeological sites are shown on records. A free software in which complex models and simulations of electromagnetic wave propagations thru the modeled media can be made is matGPR that runs in Matlab.

In soil may exist materials of various physical characteristics, shapes, sizes, influencing the electromagnetic radiation propagation [1]. They can lead to signal attenuation, reflections of different intensity, and many others anomalies making it difficult to interpret the data. Simulations can validate the interpretations of acquired data following investigations using GPR method.

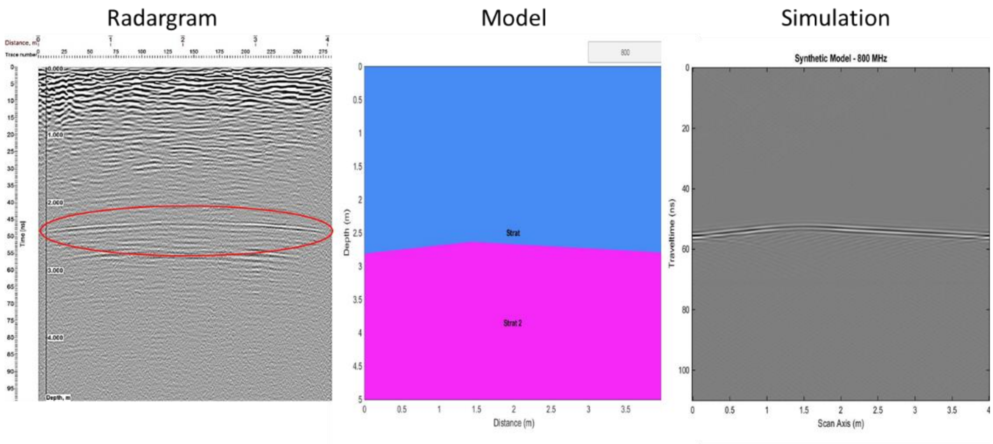
## 2. MODELING AND SIMULATING USING MATGPR

matGPR is a free software used for radargrams processing, environment modeling and simulations of electromagnetic wave propagation through the model created [2]. The model is built by overlapping layers over the background (defined by physical characteristics). Areas of shapes, sizes (polygons and circles) and different physical characteristics can be added (background resistivity, relative dielectric constant and relative magnetic permeability). The processing is influenced by the layers order, the calculations for areas where overlaps of different features exist are performed based on the last layer added.

Model size is set at the modeling beginning, respectively length (distance traveled with the equipment during the measurement whose radargrams interpretation is desired to check) and width (representing investigated depth) to obtain a simulation of equal size with the radargram. Also at this step is set the central frequency of the antenna used in investigations, so the simulation can be done for the same frequency. Using the antenna frequency and the physical characteristics of the materials from the model the propagation speed of radiation through the environment created is calculated. Geometric shapes can be inserted, that represent buried objects / structures or soil layers, they can be modified such as changing the name, position, size, physical characteristics, deleting etc.

The simulation is done using split-step (Fourier) method, which is a numerical method used to solve nonlinear partial differential equations [3]. The method resolves the solution in small steps, calculating the linear and non-linear areas separately. This technique takes into consideration the attenuation and dispersion produced by the soil inhomogeneity.

## 3. VALIDATING THE INTERPRETATION OF RADARGRAMS OBTAINED FROM ROMANIAN GPR INVESTIGATIONS

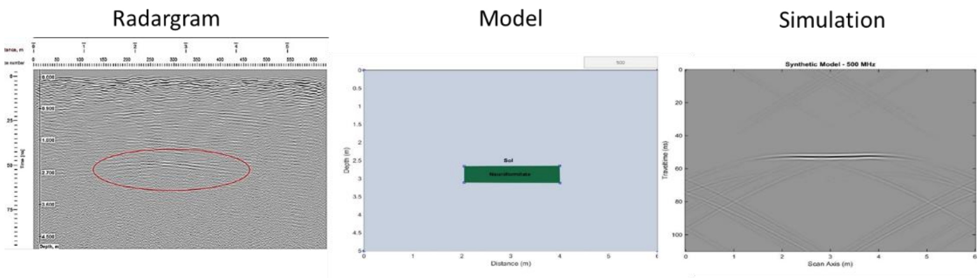



*The first example: stratigraphy differences*. First radargram presented was obtained after an investigation carried out inside the Holy Archangels church of the Baia de Arama Monastery using 800 MHz antenna. The measurement from the altar shows a strong reflection on the entire length of the recording, at 2.5 m depth (calculated using the travel time of electromagnetic radiation and an environment relative dielectric permittivity of 9) [4]. The presence of this response may signify a change in soil component, most likely, by the nature of the detected signal, the rock on which the church exist.

The model was created by overlaying a second layer, starting with the same depth of the response on radargram, with a lower relative dielectric permittivity than the first layer. In the simulation was obtained an identical response with the one from the radargram. A noticeable difference between the two images is the presence of numerous reflections in the in situ radargram, due to the unevenness of the ground, bumps that were not entered into the model.

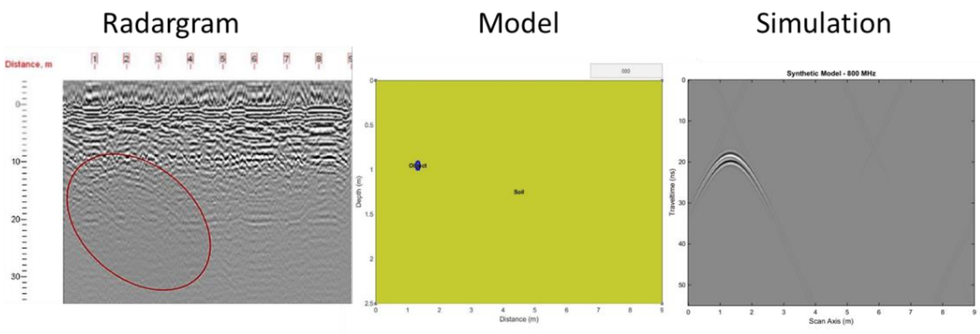
*The second example: buried object of large dimensions*. The second radargram presented was obtained at the same church, on the veranda using the 500 MHz antenna. At a depth of approximately 2.5 meters is observed a reflection that due to the depth and dimension can mark the existence of a grave. For modeling was used a background soil with a relative dielectric permittivity equal to 9 and a 2 m × 0.5 m size rectangle with a smaller relative permittivity, positioned in the area where the reflection where obtained.

In the simulation it was achieved the same response as in radargram, so assuming the existence of a tomb in this recording area is confirmed. In the simulated image, due to lack of absorbent edges strong reflections can be observed.




*Third Example*: *small buried object.* The third radargram presented radargram is from a survey done at the Roman fort and baths from Mălăieşti site, Prahova County, an archaeological site dated to the early second century. In this it can be seen a hyperbolic reflection marking the presence of a buried object or structure at a depth of about 0.7 meters.

The model was created by placing a small object in the position where the heights point of the hyperbole was recorded. Relative dielectric permittivity of the background was chosen 9, and of the buried object 7. The same answer was obtained in the simulation, confirming the existence of a small buried object.




## 4. CONCLUSION

In this paper it was briefly presented a method of validating the radargrams interpretation using a modeling and simulation of electromagnetic radiation propagation. Also three radargrams were presented obtained from investigations carried out in two different locations from Romania along with their interpretations. They were chosen because it presents three different types of response, due to differences in stratigraphy (continuous line visible on the border between layers), a large buried object (hyperbole payment) and one object of small dimensions (hyperbola). Following the modeling and simulation, the interpretations made have been validated. matGPR program can be used in the absence of data acquired in situ, in order to better understand the propagation of the electromagnetic radiation in complex environments and also for radargrams processing.

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