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Original Paper

Detecting the location of unmarked graves for archaeological purposes using Ground-Penetrating Radar (GPR)

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Abstract

Ground penetrating radar (GPR) is a non-destructive evaluation geophysical method that is able to detect and imaging the all kinds of human handmade structures, subsurface heterogeneities caused by buried objects, identifying empty spaces and cavities in environments and shallow buried targets. GPR has many applications in diverse fields of engineering and science. In the present research, the ability of employing GPR method to detect and determine the location of unmarked graves and buried corps, for archaeological purposes and similar cases has been investigated. In Iran country, the GPR method has not been widely used in archeology, especially for discovery of unmarked graves and detection of buried corps. In many areas of Iran, there are ancient cemeteries and historical tombs that require applying non-destructive and efficient geophysical methods such as GPR method in order for complete subsurface identification. To detect the exact location of unmarked graves and identification of underground human bodies by archaeogeophysical methods, having complete knowledge of the size of the human body's skeleton (bones), dimensions and material types of various coffins, mummy types and the effect of mummy on the permanence time of the body, decomposition of a corpse, procedure of body burial in different religions and burial depth of corpse is required. To achieve the goal, simulation and forward modeling of GPR data using 2D finite-different method improved in the frequency domain, has been carried out for synthetic models corresponding to empty graves, bones of human body's members as well as coffins with kinds of materials (wooden and metallic). The most of traditional coffins are wooden with the variety of designs and styles whereas relatively newer ones are made from metal. For this reason, these two types are used for modeling. In forward modeling of synthetic models, the central frequency of antenna was selected about 250MHz to 500MHz. The host medium of targets was chosen from silty clay soil, dry sand and gravel or sandy soil. In order to avoid numerical dispersion, the spatial discretization intervals (grid dimensions) along the X and Z axes were determined equal to 0.01m. Also to prevent numerical instability, temporal sampling rate was set to 0.005ns. Since in reality, coffins are usually at depths of 1ft to 2ft, in the simulations burial depth of upper surface of the coffin or corps was set to 0.8m to 1.2m and the overall depth of the grave was considered maximum 2m. According to the results of the forward modeling, regarding an empty grave, the response of the target top is as hyperbolic with a flat peak while for the bottom of the model is a defective hyperbolic with a flat peak. Therefore, in interpreting the results of actual GPR radargrams this type of response indicates the presence of a cubic structure like a buried grave. In general, the GPR response of the human's body represents itself as a hyperbolic reflection. For a buried target with a geometrical shape like a wooden coffin filled with air, the response of top and

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bottom of the coffin is clearly distinguished and the reflection intensity off both responses is relatively strong. Regarding the metallic coffin the response of top is stronger than the wooden one but there is no reflection from its bottom that is due to the strong reflection off the metal and the high attenuation of the electromagnetic waves by the metals. Also in order to investigate the subsurface of the pretty old cemetery, real GPR data was acquired using a GPR system equipped with 800 MHz central frequency shielded antenna. The finalized radargram along one of the surveyed profiles in the studied area through applying various sequence processing containing static correction, dewow filter, band-pass filter, background removal and stacking on the GPR raw data using Reflexw software has also been provided. The results of this research, on the basis of produced GPR responses for the variety of synthetic models and the radargram of real GPR data, show the capability of application of GPR method for archaeological investigations to detect and locate hidden graves, coffins and human corps by expending low cost in a short time without any manipulation and destruction of the environment.

Keywords: Archaeometry, Geophysics, Ground-penetrating radar (GPR), Forward modeling, Grave, Bone