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Performance of GPR Influenced by Electrical Conductivity and Dielectric Constant

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Abstract

The geological radar or GPR (Ground Penetrating Radar) is an electromagnetic system used in non-destructive investigations of subsoil. It is based on the emission by an antenna coupled to the ground, of short electromagnetic pulses of harmonic waves sweeping a certain frequency band. We discuss in this work, the simulation of radar signals GPR, using Reflexw. Note, however, that the operation of this program is based on numerical methods including finite difference method time domain (FDTD) for this software. The simulations we have performed include the following items: an iron bar, a plastic tube and a plastic water bottle. Have led us to find that the electromagnetic waves are very sensitive to variations in the dielectric permittivity and electrical conductivity.

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Keywords: Ground Penetrating Radar; electrical conductivity; dielectric constant; influence.

1. Introduction

The purpose of this part is to make a theoretical study by simulating the propagation of electromagnetic waves from the ground radar in heterogeneous media (geological). The phenomenon of propagation will be considered through the reflected waves: principle on which the GPR work [1, 2].

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The software Reflexw, enabled us the simulation of the ground as a function of its electrical and magnetic parameters. A number of models have been designed to simulate the variety of geological conditions. A rectangular block was used an initial model for simulation. The first model is a simple profile to give an idea on the propagation of electromagnetic waves in different materials and the effects of electromagnetic parameters (σ, ε and μ) on the wave. The second model is used to study the propagation of electromagnetic waves (reflected waves) in geological backgrounds from radargrams.

Ground-penetrating radar (GPR) is a geophysical method that employs an electromagnetic technique. The method transmits and receives radio waves to probe the subsurface. And the method has been extensively used in many applications, such as archaeology, civil engineering, forensics, geology and utility detection [3].

Dielectric constant of the host material plays an important role in GPR technology [5]. Finding out the velocity and the depth of the target dielectric constant is important. In this study it is aimed to identify the behavior of GPR waves under different dielectric constant of the hosting material [6]. The electrical properties of the ground directly beneath a ground penetrating radar (GPR) antenna very close to the earth's surface (ground-coupled) must be known in order to predict the antenna response. In order to investigate changing antenna response with varying ground properties, a series of finite difference time domain (FDTD) simulations were made for a bi-static (fixed horizontal offset between transmitting and receiving antennas) antenna array over a homogeneous ground [10, 7]. The FDTD approach to the numerical solution of Maxwell's equations is to discretize both the space and time continua. Thus, the spatial and temporal discretization steps play a very significant role since the smaller they are the closer the FDTD model is to a real representation of the problem [8]. However, the values of the discretization steps always have to be finite, since computers have a limited amount of storage and finite processing speed. Hence, the FDTD model represents a discretized version of the real problem and of limited. Construction and Building Materials [9]. The building block of this discretized FDTD grid is the Yee cell named after Kane Yee who pioneered the FDTD method [4, 11]. The interactions of EM waves with physical media can be quite complex and the most exact models known for EM interactions use quantum mechanics [12].

2. Theoretical background

EM in subsurface material is dominate by Maxwell's equation and its behavior in subsurface material is strongly dependent on its electrical conductivity and dielectric constant (ε_r) and we can express the electric and magnetic fields as in equation 1

$$\begin{aligned} \Delta \times E &= -jw\mu H \\ \Delta \times H &= E\sigma + w\varepsilon E \end{aligned} \tag{1}$$

The radar wavelet propagates through the soil while the velocity of the wavelet depends on the dielectric properties of the ground as Eq 2:

$$v = c \Big/ \sqrt{\varepsilon_r} \tag{2}$$

GPR transmits a pulsed electromagnetic wave from a transmitter and signals are received by a receiving antenna. The transmitted signal propagates through the subsurface material and reflected by objects given through Eq 3 and refraction of electromagnetic waves is formulated by Snell's law Eq 4 [3]:

$$R = \left(\sqrt{\varepsilon_2} - \sqrt{\varepsilon_1}\right) \Big/ \left(\sqrt{\varepsilon_2} + \sqrt{\varepsilon_1}\right) \tag{3}$$

$$\sin\alpha_1 / \nu_1 = \sin\alpha_2 / \nu_2 \tag{4}$$

where α_1, α_2 are attenuation coefficient of materials.