2-1/2 DIMENSIONAL BISTATIC GPR PROPAGATION AND SCATTERING MODELING OF ROADWAYS AND TUNNELS WITH PROJECTED 2D FDTD

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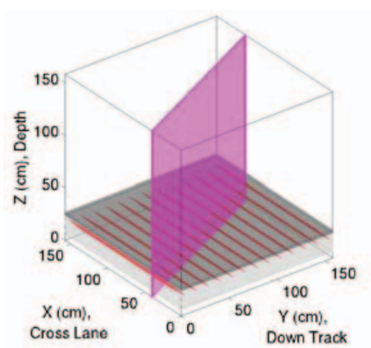
Abstract

Subsurface sensing modalities such as Ground Penetrating Radar (GPR) are increasingly being used to assess the condition of aging civil infrastructure by evaluating deterioration within roadways and bridges, and to monitor the security of national borders by the detection of underground tunnels. The need to address these issues is intensifying and, while valuable data are collected using nondestructive evaluation there is urgency for improved understanding and analysis. Computational modeling via a Finite Difference Time Domain (FDTD) formulation is widely used to analyze electromagnetic wave propagation and can provide insight integral to understanding complicated wave interactions. Simulation of GPR investigations to search for defects in bridges and the presence of underground tunnels can help to understand and analyze real world data. Ideally, a three-dimensional computational model of the region of interest would be utilized. However, in regions of relative invariance in the third dimension, two-dimensional analysis can capture much of the scattering observed in three-dimensional analysis. 2D FDTD simulations complete much quicker than 3D simulations and have significant potential to be executed in the field in real time to assist in immediate data analysis. A major shortcoming of 2D modeling is that the plane containing the bistatic transmitter and receiver – along with the path of GPR movement – must be exactly in the geometry cross-section.

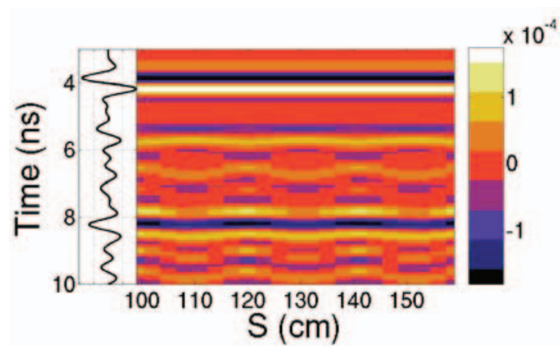
We propose the use of a 2-1/2 dimensional FDTD for the modeling of bistatic air-launched GPR propagation and scattering of roadways and tunnels using a projected 2D FDTD. The 2-1/2D FDTD avoids the specific observation plane restriction, yet it has the same computational expense as the 2D FDTD and the same computational benefits over the 3D FDTD. We will show simulated B-scan results for several examples of reinforced concrete bridge decks (in healthy and defective conditions) and underground tunnels using 3D and 2-1/2D models. To minimize differences in wave propagation between the different dimensions, a single grid point

excitation is used Particular emphasis will be placed on data not captured using the 2-1/2D FDTD model and the potential for 2-1/2D FDTD to be used to evaluate 3D data.

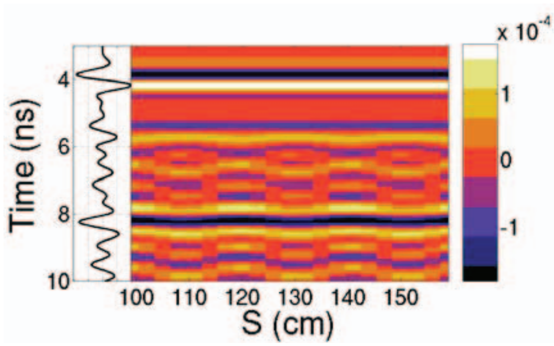
Consider the model of a bridge deck shown in Fig. 1(a) with 18cm of dry concrete deck overlaid with 2.4cm of asphalt. Reinforcing steel bars (rebars) with 1.8 cm diameters run in the cross-track direction 4.8cm below the asphalt, separated by 10.8cm. The transmitter and receiver are located 30.6cm above the surface and are separated by 3cm. B-scans are generated from the *x*-directed component of the electric field recorded at the receive antenna as the pair move along the illustrated plane at a constant height above the surface. B-scans computed from the 3D and 2-1/2D FDTD are shown in Figs. 1(b) and 1(c) respectively. Fig. 1(d) shows the difference between the B-scans. Essential rebar and layer interfaces can be seen in both the 3D and 2-1/2D B-scans, but, as will be discussed, there are some discrepancies in amplitude due to differences in wave propagation in the different dimensions and the severe angle of the 2-1/2D plane. The introduction of defects in the subsurface and invariance in the 3rd dimension will result in higher differences between the B-scans. However, we will show that despite these differences, the 2-1/2D FDTD has significant potential to analyze 3D data.



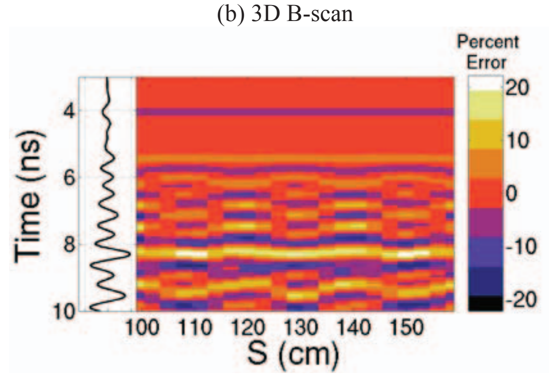
(a) 3D deck geometry illustrating plane used in 2-1/2D FDTD



(b) 3D B-scan



(c) 2-1/2D B-scan



(d) Difference between 3D and 2-1/2D B-scans. Note color axis is different from (b) and (c).

Figure 1. B-scan comparison of 3D and 2-1/2D scattering of a bridge deck due to a 1GHz excitation pulse.