An efficient FDTD solution for seismic plane-wave responses of vertically heterogeneous viscoelastic media

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Real Earth media disperse and attenuate propagating seismic waves. This anelastic behavior can be described well by a viscoelastic model. It is possible to represent viscoelastic behavior by using mechanical models of combination of spring and dashpots. There are several rheological models that represent viscoelastic behavior, such as Maxwell, Kelvin-Voiget, and Standard Linear models. To incorporate viscoelastisity in wave equation we need to drive stress-strain relation for these models. Among them, the Standard Linear model is more common than others to be used for derivation of viscoelastic wave equation. In this paper after representing different rheological models, the Standard Linear model has been used to derive the viscoelastic wave equation for vertically inhomogenous structure. For this purpose, viscoelastic coefficients are derived and a memory variable is introduced to incorporate the time dependent behavior of anelasticity. Plane-wave responses of vertically heterogonous structure models (1-D media) are often computed in seismology. In this study we develop an efficient procedure to calculate the plane wave response of arbitrary 1-D viscoelastic media using the finite-difference method in time domain (FDTD). To incorporate the viscoelasticity in wave equation we used the Standard Linear Solid (SLS) model. The main parameters of the SLS model are stress and strain relaxation times which can be calculated for different Q values of P and S waves. We first drive a viscoelastic wave equation for a plane-wave incidence problem for vertically heterogonous media by applying the Snell's law to the 3-D wave equation. We then discretize the velocity-stress formulation of the derived equation using a staggered-grid finite-difference scheme of fourth-order accurate in space and second order accurate in time. We developed and revised a proper Fortran code for the calculation based on the code written by Tanaka & Takenaka (2003) for the elastic case.