Elastic-wave scattering from an object above a rough surface: A numerical time-domain technique

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We developed a scattering model for layered media by introducing a π-shaped total field area over an irregular surface. This novel method utilizes the unique features of the finite-difference time-domain (FDTD) [1] and complex frequency shifted perfectly matched layer (CFS-PML) [2]. We use an auxiliary variable employed in PML formulation presented by Drossaert and Giannopoulos [2] to isolate the reflected and transmitted waves from the incident wave. Although such methods are well formulated for electromagnetic wave scattering, such formulation presented in this work is new for the elastic wave scattering. The present theory allows one to capture the scattering response for the problems containing complex scattering geometries, such as rough surfaces and interfaces in nanostructured layered media. This new formulation is suitable for precise calculation of the scattering cross-section with significantly less iteration time compared to analytical methods.

The backscattering from a random rough surface of 30 nm width and the 10 nm diameter circular inclusion above the surface are presented to show the effectiveness of the proposed formulation. The reflection/transmission behavior and the frequency response are illustrated. The scattering object under investigation is located within the FDTD volume, illuminated by a broadband pulsed plane wave centered at 2 GHz and scattered fields are simulated all around the object via FDTD directly in time domain. The mass density and Lame parameters of silicon as the main domain material and aluminum as the scattering object are used as input for the elastic wave equation.

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[1] L. N. Maurer, S. Mei, and I. Knezevic, Phys. Rev. B **94**, 45312 (2016).

[2] F. H. Drossaert and A. Giannopoulos, Wave Motion **44**, 593 (2007).

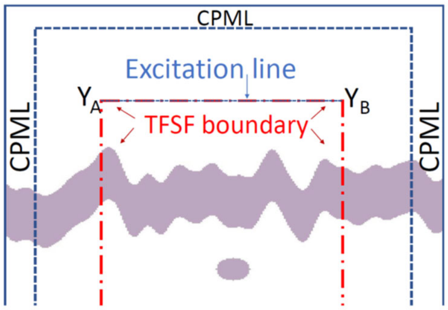

Fig.1: Schematic of a π-shaped TFSF boundary around a random rough surface and terminated by CPML absorbing boundary.

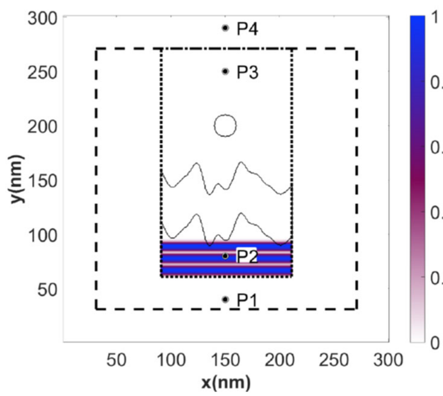

Fig.2: Snapshot of the spatial profile of the energy density captured after 0.8 ns.

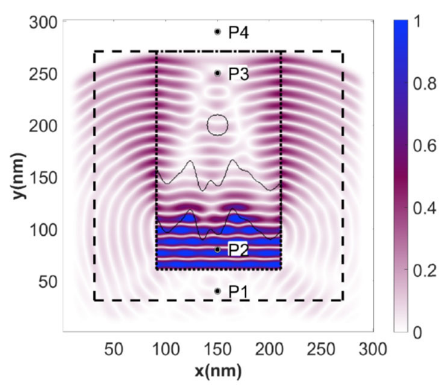

Fig.3: Snapshot of the spatial profile of the scattered and reflected energy density 4.7 ns after the launch of the source wave.

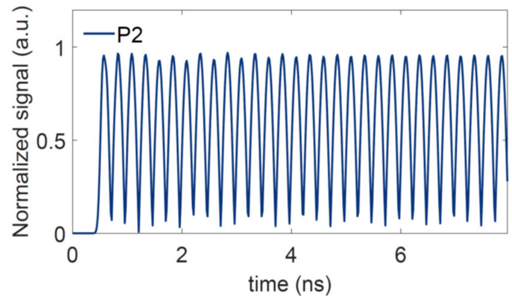

Fig. 4: The energy density captured at point P2 from Fig. 2, consist of the incident wave and reflected wave from the interface normalized to the source's maximum amplitude.

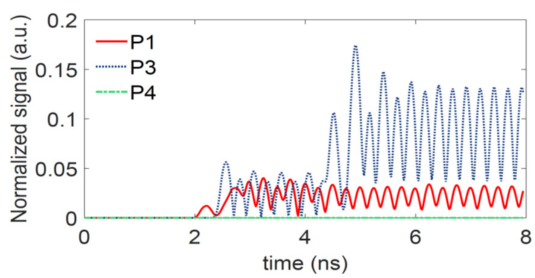

Fig.5: The energy density captured at point P1, P3 and P4; P1 is the reflected wave from the interface without source interference, P3 transmitted wave, scattered by the surface and the inclusion; and P4 wave absorbed by the CPML absorbing boundary; all normalized to the source's maximum amplitude.

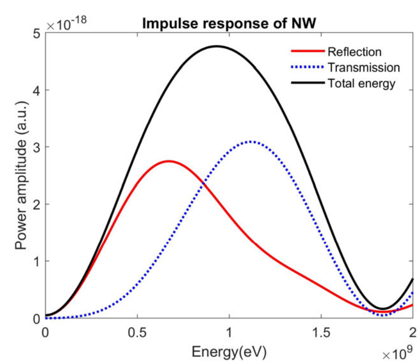

Fig.6: Impulse response of reflected and transmitted energy from and through the scattering objects

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