SDSU Module: A Hybrid Broadband Synthetics Generator Using High-Frequency Scattering Functions.

Kim Bak Olsen (kbolsen@sdsu.edu), Rumi Takedatsu (rtakedatsu@sdsu.edu), Nan Wang (naw021@ucsd.edu)

San Diego State University, San Diego, CA, USA

Release Notes (V. 19.4)

This release of the SCEC BBP SDSU Module includes a series of changes, in addition to the use of Green's functions with a minimum Vs of 500 m/s. Here, we have changed the merging of the low-frequency (LF) and high-frequency (HF) synthetics from the previous approach in the frequency domain (Mai et al., 2010) to the time domain, using matched filtering. The time domain merging procedure was found to generate less artifacts at the merging frequency. We have also incorporated inter-frequency correlation in the SDSU Module, essentially as a post-processing method, by applying an empirical correlation matrix to the Fourier amplitudes of the synthetic ground motion time series (Wang et al., in prep., describes the methods and shows validation for 7 western US events). Figure 1 shows a comparison of the inter-frequency correlation structure for the Loma Prieta event before and after applying our method. We have changed the recommendation for the high-frequency exponent fdec in the $Q(f)= Q_o f^{fdec}$ for WUS to 0.5 rather than previously 0.8, to obtain a better fit of the PSA from the synthetics to that from data, specifically for part B. Finally, we have incorporated the same dependency of rake and dip on the ground motion as introduced by Graves and Pitarka (2015):

$$\alpha_T = [1 + F_D F_R c_\alpha]^{-1}$$

with the dip (F_D) and rake (F_R) factors given by

$$F_D = \begin{cases} 1 - \frac{(\delta - 45°)}{45°}, & 45° < \delta \le 90° \\ 1, & \delta \le 45° \end{cases}$$

and

$$F_R = \begin{cases} 1 - \frac{|\lambda - 90°|}{90°}, & 0 \le \lambda \le 180° \\ 0, & \text{otherwise} \end{cases},$$

and $c_\alpha = 0.1$.

We continue to use the Graves & Pitarka rupture generator on the SCEC BBP for the SDSU Module.

Method Overview

For computing broadband hybrid seismograms using the SDSU broadband synthetics rupture generator on the SCEC BBP, we adopt a three-stage approach. First, we calculate LF synthetics for a finite-fault earthquake rupture embedded in a 1D Earth model using the Graves and Pitarka rupture generator. Second, we generate HF scattering contributions for each observer location, considering path-averaged scattering properties and local site conditions based on site kappa (κ). The HF scatterograms are generated for each component of motion based on the theory for multiple S-to-S, S-to-P and P-to-S scattering by Zeng et al. (1991, 1993). The scatterograms are based on user-specified site-scattering parameters and are partly based on the site-specific velocity structure. The seismic-scattering wave energy is realized to appear after the direct P-wave arrival time, which is found from 3D ray tracing (Hole, 1992). Finally, the scatterograms are convolved with an appropriate source time function. It is assumed that the scattering operators and moment release originate throughout the fault but start at the hypocenter. Finally, the two sets of seismograms are reconciled to form hybrid broadband seismograms using matched filtering in the time domain. Additional frequency-dependent site-effect corrections can be applied to the broadband synthetics. The SDSU BBP module participated in and passed the SCEC BBP validation exercise (Goulet et al., 2015).

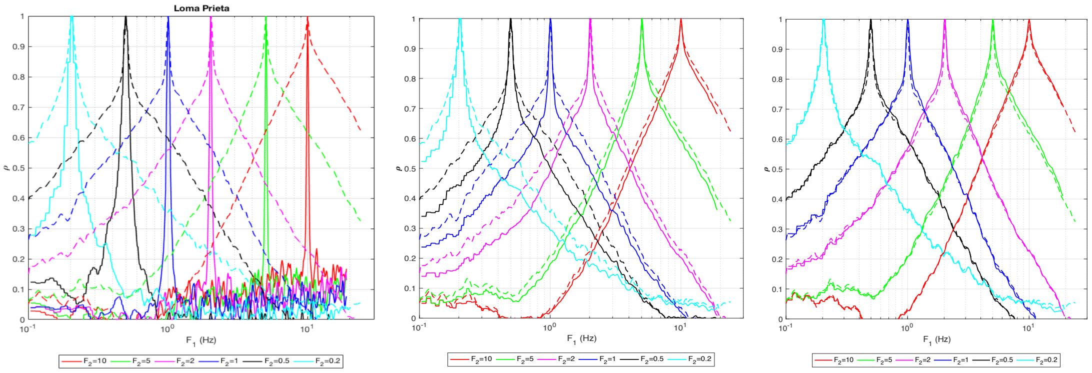

Figure 1. The inter-frequency correlation coefficients of epsilon at reference frequencies 0.2 Hz, 0.5 Hz, 1 Hz, 2 Hz, 5 Hz and 10 Hz from the empirical correlation coefficients (dashed lines) and the SDSU SCEC BBP Module (left) before applying our method, (center) using independent random variables at two horizontal components (solid lines), and (right) using correlated random variables (with correlation coefficient equals 0.7) at two horizontal components (solid lines) for the Loma Prieta event.

References

Goulet, C., Abrahamson, N., Somerville, P., & Wooddell, K. (2015). The SCEC Broadband Platform validation exercise for pseudo‐spectral acceleration: Methodology for code validation in the context of seismic hazard analyses. *Seismological Research Letters, 86*(1).

Graves, R., & Pitarka, A. (2015). Refinements to the Graves and Pitarka (2010) broadband ground‐motion simulation method. *Seismological Research Letters, 86*(1), 75-80.

Hole, J. A. (1992). Nonlinear high‐resolution three‐dimensional seismic travel time tomography. *Journal of Geophysical Research: Solid Earth, 97*(B5), 6553-6562.

Mai, P.M., W. Imperatori, and K.B. Olsen (2010). Hybrid broadband ground-motion simulations: combining long-period deterministic synthetics with high-frequency multiple S-to-S back-scattering, Bull. Seis. Soc. Am. 100, 5A, 2124-2142.

Mena, B., P.M. Mai, K.B. Olsen, M.D. Purvance, and J.N. Brune (2010). Hybrid broadband ground motion simulation using scattering Green's functions: application to large magnitude events, Bull. Seis. Soc. Am. 100, 5A, 2143-2162.

Olsen, K.B, R. Takedatsu (2015). The SDSU Broadband Ground-Motion Generation Module BBtoolbox Version 1.5, Seism. Res. Lett. 86,1, 81-88.

Wang, N., R. Takedatsu, K.B. Olsen, and S.M. Day (2019). Broadband Ground-Motion Simulation with Inter-Frequency Correlations (in preparation for submission).

Zeng, Y., Aki, K., & Teng, T.‐L. (1993). Mapping of the high‐frequency source radiation for the Loma Prieta earthquake, California. *Journal of Geophysical Research: Solid Earth, 98*(B7), 11981-11993.