EXSIM Method: A Stochastic Extended Finite-Fault Ground-Motion Simulation Algorithm

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Release Note

In the new release, a new set of amplification factors are developed to be used for Japan and California, which are presented in Table 1. These factors are developed for a site with V_{S30} = 500 m/s (time-averaged shear-wave velocity in the top 30m), by scaling of the amplification factors used in Assatourians and Atkinson (2015) (VS30 = 760 m/s) according to the V_{S30} scaling model of Seyhan and Stewart (2014). The rest of the input parameters are the same as the ones presented in Assatourians and Atkinson (2015).

Table 1. Input Site amplification factors for Japan and California, for a reference site with V_{S30} = 500 m/s.

Frequency (Hz)	Amplification Japan	Frequency (Hz)	Amplification California
0.11	1.39	0.00	1.45
0.22	1.62	0.10	1.45
0.41	1.84	0.24	1.87
0.64	1.92	0.45	2.17
0.80	1.97	0.79	2.48
0.99	2.05	1.38	2.91
1.23	2.13	1.93	3.20
1.53	2.28	2.85	3.36
1.90	2.44	4.03	3.35
2.37	2.60	6.34	3.13
2.94	2.78	12.54	2.95
3.66	3.10	21.23	2.99
4.55	3.23	33.39	3.11
5.66	3.43	82.00	3.23
7.04	3.66		
8.75	3.71		
10.90	3.55		
13.50	3.03		

Method Overview

EXSIM is an open-source stochastic extended finite-source simulation algorithm, written in FORTRAN, that generates time series of ground motion for earthquakes (Motazedian and Atkinson, 2005; Boore, 2009; Assatourians and Atkinson, 2012). To consider the finite-fault effects (e.g. faulting geometry, distributed rupture, and rupture inhomogeneity) in ground-motion modeling, EXSIM subdivides the fault surface of an earthquake into a grid of sub-sources, each of which could be treated as a point source. Time series from the sub-sources are modelled using the point-source stochastic model developed by Boore (1983, 2003) and popularized by the Stochastic-Method SIMulation (SMSIM) computer code (Boore, 2003, 2005). The stochastic point-source model assumes that the source process is concentrated at a point and that the acceleration time series radiated to a site carry deterministic and random aspects of ground-motion shaking. The deterministic aspects are specified by the average Fourier spectrum, given as a function of magnitude and distance. The stochastic aspects are treated by modeling the motions as Gaussian noise with the specified underlying spectrum. The underlying deterministic spectrum is a multiplication of source term (Brune, 1970 & 1971) (Fourier spectrum at the source defines by seismic moment and stress parameter), path term (anelastic attenuation and geometrical spreading), and site term (crustal amplification and near-surface attenuation). EXSIM also uses the concept of dynamic corner frequency (Motazedian and Atkinson, 2005) in which the rupture begins with a high corner frequency and progresses to lower corner frequencies as the ruptured area grows. This makes the simulation results relatively insensitive to sub-source size. The duration of motion for each sub-source comes from the source duration plus the path duration. Finally, the time series from the sub-sources are summed in the time domain with a normalization factor, with appropriate time delays for propagation of the rupture front. This would result into a total seismic signal at a site of interest.

References

Assatourians, K., and G. Atkinson (2012). EXSIM12: A Stochastic Finite- Fault Computer Program in FORTRAN, http://www.seismotoolbox.ca (last accessed April 2019).

Atkinson, G. M., and K. Assatourians (2015). Implementation and validation of EXSIM (a stochastic finite-fault ground-motion simulation algorithm, Seismol. Res. Lett. 86, no. 1, doi: 10.1785/ 0220140097.

Boore, D. M. (2003). Simulation of ground motion using the stochastic method, Pure Appl. Geophys. 160, 635–675.

Boore, D. M. (2005). SMSIM—Fortran Programs for Simulating Ground Motions from Earthquakes: Version 2.3—A Revision of OFR 96–80– A, http://www.daveboore.com/software_online.html (last accessed April 2019).

Boore, D. M. (2009). Comparing stochastic point-source and finite-source ground-motion simulations: SMSIM and EXSIM, Bull. Seismol. Soc. Am. 99, 3202–3216.

Brune, J. N. (1970). Tectonic stress and the spectra of seismic shear waves from earthquakes, J. Geophys. Res. 75, 4997–5009.

Brune, J. N. (1971). Tectonic stress and the spectra of seismic shear waves from earthquakes: Correction, J. Geophys. Res. 76, 5002.

Motazedian, D., and G. M. Atkinson (2005). Stochastic finite-fault modeling based on a dynamic corner frequency, Bull. Seismol. Soc. Am. 95, 995–1010.

Seyhan, E., and J.P. Stewart (2014). Semi-empirical nonlinear site amplification from NGA-West2 data and simulations, Earthquake Spectra. 30 1241-1256.