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Inter-Period Correlations of SCEC Broadband Platform Fourier Amplitudes and Response Spectra

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GMSV

(I) Background

The SCEC Broadband Ground Motion Simulation Platform (BBP) has become an important resource for researchers and practitioners who need to use strong ground motion simulations. Recently, the first validation phase of the SCEC BBP was evaluated for the suitability of simulated pseudo-spectral acceleration (PSA) for use in engineering applications (Dreger et al., 2013 and Goulet et al., 2015). The Dreger et al. (2013) validation exercise was an important first step towards a more complete validation of the SCEC BBP. Future validation activities for the BBP include: repeating the Dreger et al. (2013) validation of median PSA for a larger set of validation events, incorporating bending fault models and multi-segment models guided by the results from dynamic models, implementing improved site response methods, and assessing and validating the variability of simulated ground motions.

Epsilon (ϵ) is the normalized difference between the intensity measure of a simulated ground motion and the median model. The inter-period correlation of ϵ is one ground motion variability parameter which needs to be tested and validated, since it is related to spectral shape (the width of peaks and troughs in the spectra) and is shown to be an important feature for the response of MDOF structures.

(II) Objectives

Implement a validation scheme for the inter-period correlation of ϵ for both PSA and Fourier amplitude spectra (FAS) of simulated ground motions on the SCEC BBP. This includes the following:

- Implement and verify computer codes on the SCEC BBP for the calculation of the FAS (including smoothing)
- Develop a model for the simulated FAS, from which ϵ is calculated
- Calculate the inter-period correlation of ϵ for both the FAS and PSA.
- Assess the behavior for all available simulation methods

(Equation 1)

$$EAS(f) = \sqrt{\frac{1}{2}\left[FAS_{H1}^2(f) + FAS_{H2}^2(f)\right]}$$

(Equation 2)

$$\ln(EAS) = c_1 + c_2M + c_3M^2 + (c_4+c_5M)\ln\left(\sqrt{R^2+c_6^2}\right) - c_7\sqrt{R^2+c_6^2} + c_8\ln\left(\frac{V_{s30}}{V_{sref}}\right) + c_9Z_{tor} + c_{10}F_{NML} + c_{11}F_{RV}$$

(Equation 3)

$$\rho = e^{\left(-c_1 * \ln\left(\frac{F_2}{F_1}\right)\right)}$$

(1) Introduction

- The inter-period correlation of ϵ is a ground motion variability parameter which needs to be tested and validated in simulations, since it is related to spectral shape (the central periods and widths of peaks and troughs in the spectra) and is an important feature for the response of MDOF structures (Bayless and Abrahamson, 2016, in preparation).
- Burks and Baker (2014) evaluated the inter-period correlation of within-event PSA ϵ of three SCEC BBP simulation methods using the Loma Prieta earthquake. Results were compared with empirical models, and those results varied depending on the simulation method and frequency range. Based on their results, we believe there is significant room for improvement.
- We have chosen to work with FAS instead of PSA so that the empirical model we develop for the inter-period correlation of within-event FAS ϵ can be more readily incorporated into the simulation modules.

(2) Empirical Model for ρ_{EAS}

In a related study, we have developed a simple GMPE for the FAS:

- Database: a subset of the PEER NGA-West 2 FAS database, screened for poor recordings and undesirable earthquakes (Abrahamson et al, 2013) (Figure 1)
- Effective amplitude spectrum (EAS) component (Equation 1) of the FAS, smoothed with log-spaced operator (Konno and Ohmachi 1998)
- Non-linear mixed effects regression
- Point source formulation (Equation 2)
- Frequency range: 0.1 – 24 Hz
- The model scales properly with Mag, distance, Vs30, and other parameters, and residuals are checked visually

From this model, ϵ is calculated for each record at each frequency. We calculate the correlation of epsilon at each frequency pair for the database (Figures 2 and 3) and develop a simple model for the correlation of ϵ (Figure 4, Equation 3). This model is independent of the conditioning frequency. We plan to update this model with a more complex one in the future.

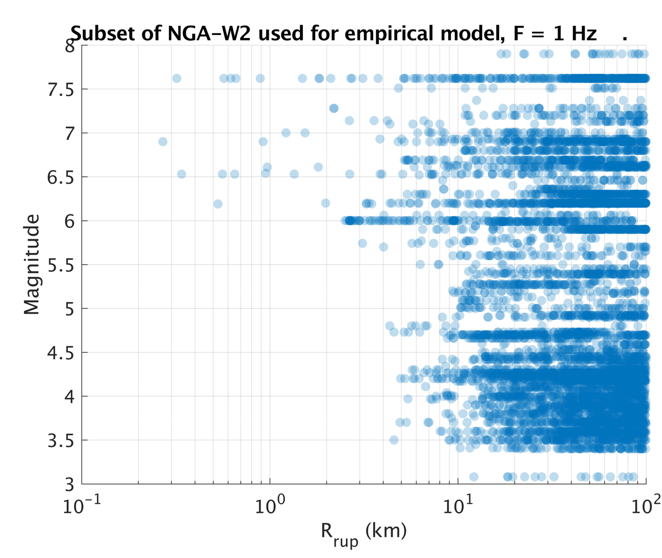

Figure 1: EAS database

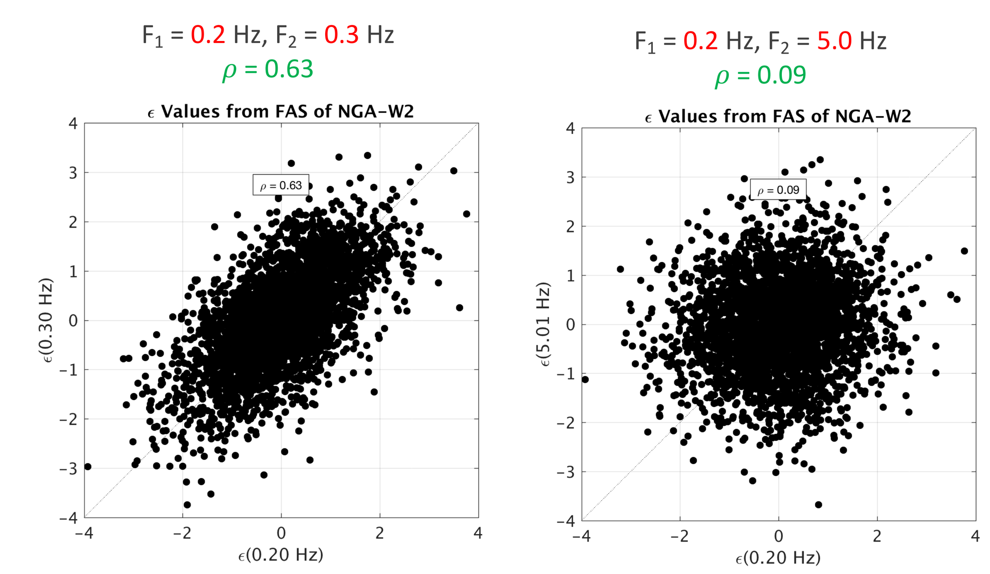

Figure 2: Example correlation of EAS ϵ at two frequency pairs

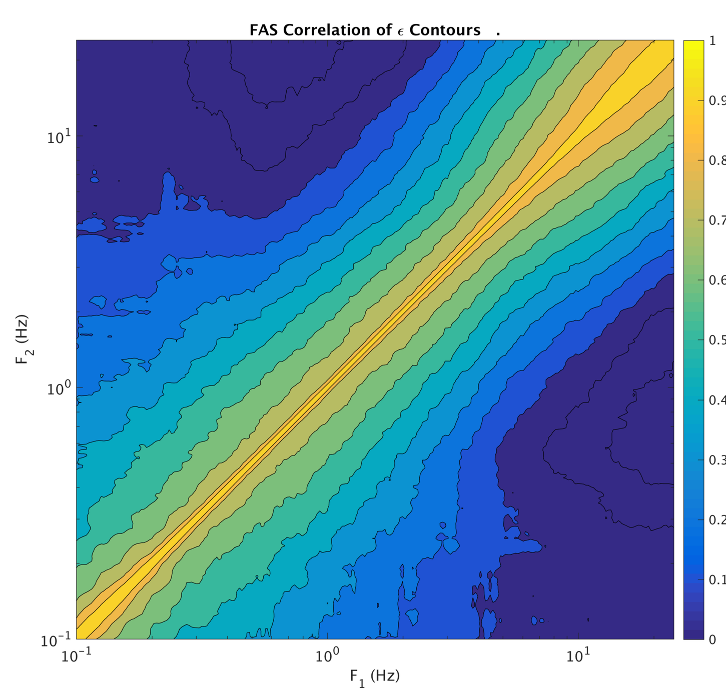

Figure 3: Correlation of EAS ϵ contours

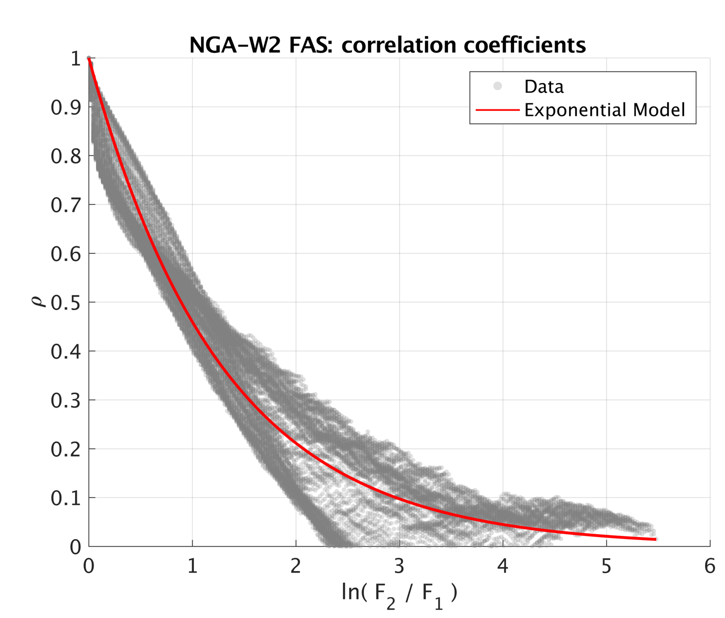

Figure 4: Correlation of EAS ϵ exponential model

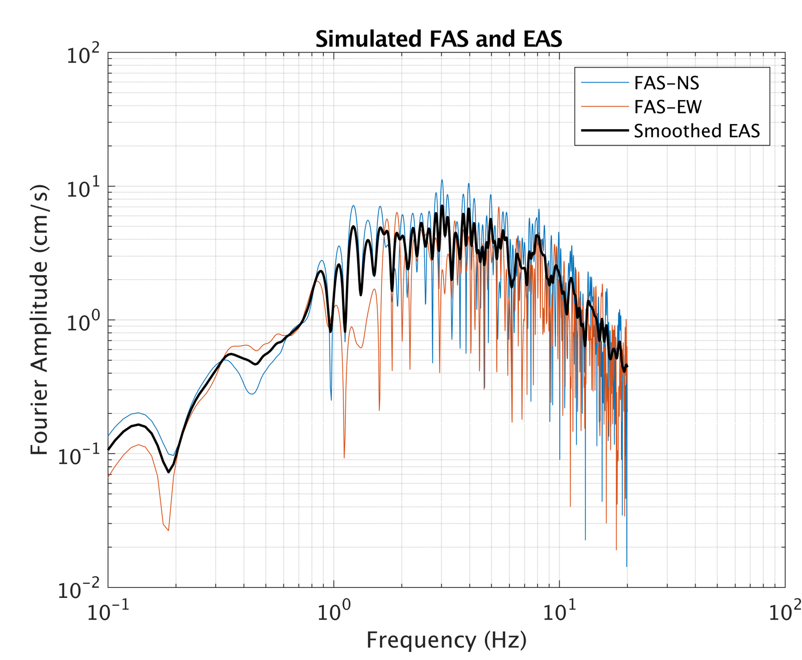

Figure 5: FAS and smoothed EAS calculation

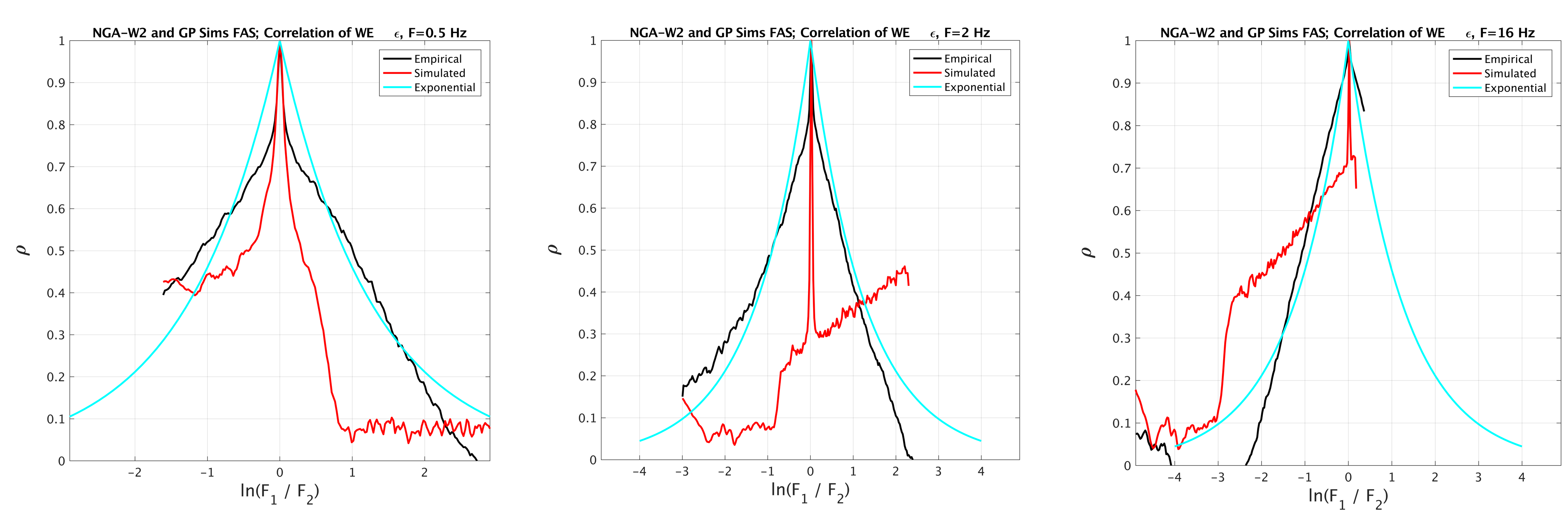

Figure 6: Correlation of EAS ϵ cross sections for F = 0.5, 2.0, and 16 Hz

(3) Evaluation of Simulations

- Implement codes for the FAS and EAS calculation on the SCEC BBP
- Implement codes for smoothing of the EAS, consistent with the NGA-W2 database
- Gather SCEC BBP simulations, calculate the smoothed EAS (Figure 5)
- Calculate residuals
  - Requires an EAS model. We are currently in the process of testing different models. The simplest one would be the EAS model developed in (2). Another option is to develop one from the database of simulations.
- Calculate the inter-period correlation of within-event EAS ϵ
- Calculate the inter-period correlation of within-event PSA ϵ
- Compare with empirical models: Baker and Jayaram (2008) for PSA and the model developed here for FAS (Figure 6)

(4) Conclusions

We are in the process of verifying the FAS software implemented on the SCEC BBP. Then, we will evaluate the correlation of all the simulation methods available on the platform, using the latest versions of the modules. In the meantime, we have evaluated two methods manually using an outdated version of the platform (v14.3): ExSim (Atkinson and Assatourians, 2015) and Graves and Pitarka (GP, Graves and Pitarka, 2015; Graves, 2014) with simulations from three validation events: Loma Prieta, Northridge, and Landers. Figure 6 compares the GP results with the empirical correlations, and the exponential correlation model at three frequencies.

The correlation of FAS ϵ behavior varies by simulation method, but in general the inter-period correlation of the simulations drops off more rapidly (in frequency space) than the empirical model, especially at high frequencies. ExSim correlations (not shown) are low at all frequencies, as expected since this method is based on random amplitudes generated from white noise.

Once the evaluation phase is complete, we look forward to working with the SCEC BBP simulation modelers to implement the inter-period correlations of FAS ϵ into their models, where necessary.