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Modelling of DAS cable and ground coupling response using Discrete Particle Schemes

Nicolas Luca Celli, Christopher J. Bean, Gareth O'Brien, and Nima Nooshiri
Dublin Institute for Advanced Studies, School of Cosmic Physics, Geophysics Section, Dublin, Ireland (niscelli@cp.dias.ie)

Since its first applications in the past decade, the use of fiber optic cables as ground motion sensors has become a central topic for seismologists, with successful applications of Distributed Acoustic Sensing (DAS) in various key fields such as seismic monitoring, structural imaging and source characterisation.

The instrument response of DAS cables however is largely unknown. Instrument response is a combination of instrument design, local site effects and ground coupling, and for DAS, the latter ones are believed to have a strong, spatially variable, but yet largely unquantified effect. This limits the application of a large number of staple seismological techniques (e.g. earthquake magnitude estimation, waveform tomography) that can require accurate knowledge of a signal's amplitude and frequency content.

Here we present a method for accurately simulating a DAS cable and its response. The scheme is based on molecular dynamic-like particle-based numerical modelling, allowing the investigation of the effect of varying DAS-ground coupling scenarios. At first, we compute the full strain field directly, for each pair of neighbouring particles in the model. We then define a virtual DAS cable, embedded within the model and formed by a single string of interconnected particles. This allows us to control all aspects of the cable-ground coupling and their properties at an effective granular level through changing the bond strengths and bond types (e.g. nonlinearity) for both the cable and the surrounding medium. Arbitrary cable geometries and heterogeneous materials can be accommodated at the desired scale of investigation.

We observe that at the meter scale, realistic DAS materials, cable-ground coupling and the presence of unconsolidated trench materials around it dramatically affect wave propagation, each change affecting the synthetic DAS record, with differences exceeding at times the magnitude of the recorded signal. These differences show that cable coupling and local site effects have to be considered both when designing a DAS deployment and analysing its data when either true or along-cable relative amplitudes are considered.