Signal-theoretical study of wireline DAS-VSP coupling noise

Evgeniia Martuganova[1], Manfred Stiller[1], Klaus Bauer[1], Jan Henninges[1], Charlotte M. Krawczyk[1, 2] & Ernst Huenges[1, 2]

[1]GFZ German Research Centre for Geosciences, Potsdam, Germany, [2]Technical University Berlin, Germany

Distributed acoustic sensing technology is gaining more and more attention during the last decade. Measurements with a fibre-optic cable installed along the casing or behind the tubing are widely and successfully applied for borehole seismic data acquisition. Nevertheless, in a vast number of already drilled boreholes only measurements with a wireline logging cable are feasible. In the literature, only a limited number of wireline DAS experiments can be found.

First of all, the measureable physical quantities for wireline recording with DAS cables are not well understood, presumably due to the uncertainty regarding several measuring parameters. Furthermore, cable configuration inside the well is not well controllable and can result in a bad coupling with the borehole wall. A freely hanging wireline cable is exposed to slapping and ringing inside the casing, which leads to an increased level of subsurface-independent noise. As a result, additional processing steps to increase the S/N ratio accordingly are needed. Thus, for the development of the DAS wireline acquisition method, we studied this noise in more detail.

For our analysis we used a VSP dataset acquired with wireline DAS technique at the Groß Schönebeck geothermal research site, NE German Basin. The data recording was performed using wireline cable at two 4.3 km deep wells E GrSk 3/90 and Gt GrSk 4/05 with a depth sampling of 5 meters along the borehole. The 61 vibroseis source points had various offsets from 200 to 2000 meters with a layout organised as a spiral pattern around the target area to ensure a good azimuth distribution.

We propose a physical explanation for the mechanism of noise generation and draw parallels to some other similar wave propagation processes and phenomena. We examined different existing methods for coupling noise suppression and demonstrated a comparison between them. Finally, knowing the noise properties, we suggest using a matching pursuit decomposition with Gabor atoms for noise characterisation and suppression. The idea behind the method is to represent the input signal as a weighted sum of Gabor functions. By analysing the detailed noise statistics, which include frequency, phase, amplitude and position in time, we were able to identify and model those parts of the signal, which represent the slapping and ringing of the cable, and then subtract them from the recorded seismic trace. The main advantage of the method of trace decomposition is that it permits to separate the noise and the signal, even if they are overlapping both in time and frequency domain.

Improved techniques for noise detection and suppression will enable further development and application of DAS wireline acquisition, which is often more efficient in terms of time and costs compared to deployment of conventional borehole seismometers.