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Analysis of thin fractures with GPR: from theory to practice

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Whenever we perform a GPR survey to investigate a rocky medium, being the ultimate purpose of the survey either to study the stability of a rock slope or to determine the soundness of a quarried rock block, we would like mainly to detect any fracture within the investigated medium and, possibly, to estimate the parameters of the fractures, namely thickness and filling material. In most of the practical cases, rock fracture thicknesses are very small when compared to the wavelength of the electromagnetic radiation generated by the GPR systems. In such cases, fractures are to be considered as thin beds, i.e. two interfaces whose distance is smaller than GPR resolving capability, and the reflected signal is the sum of the electromagnetic reverberation within the bed. According to this, fracture parameters are encoded in the thin bed complex response and in this work we propose a methodology based on deterministic deconvolution to process amplitude and phase information in the frequency domain to estimate fracture parameters. We first present some theoretical aspects related to thin bed response and a sensitivity analysis concerning fracture thickness and filling. Secondly, we deal with GPR datasets collected both during laboratory experiments and in the facilities of quarrying activities. In the lab tests fractures were simulated by placing materials with known electromagnetic parameters and controlled thickness in between two small marble blocks, whereas field GPR surveys were performed on bigger quarried ornamental stone blocks before they were submitted to the cutting process. We show that, with basic pre-processing and the choice of a proper deconvolving signal, results are encouraging although an ambiguity between thickness and filling estimates exists when no a-priori information is available. Results can be improved by performing CMP radar surveys that are able to provide additional information (i.e. variation of thin bed response versus offset) at the expense of acquisition effort and of more complex and tricky pre-processing sequences.