Development of *Q* factor estimation through Prony spectral decomposition

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Abstract

When seismic waves propagate through the interior of the Earth, both inelasticity and heterogeneity contribute to two effects: absorption, which corresponds to the effect of dissipation, when the medium absorbs the wave's energy, and dispersion, in which different frequency components propagate at different velocities. Attenuation (a term combining the effects of absorption and dispersion) is sensitive to many essential characteristics of the rock, such as, for example, mineral composition, fluid type, saturation, porosity, permeability, pressure, temperature, fractures, faults and cavities. Thus, the importance of developing new methods for estimating the *Q* factor and its correlation with the properties of geological media is obvious.

A seismic signal can be represented using the Prony transform as a sum of damped sinusoids depending on four real-valued parameters that make up the Prony spectrum: *amplitude*, *damping factor*, *frequency* and *phase* for each sinusoid [1]. After estimating these seismic trace parameters, a procedure can be constructed to select the estimated values based on various criteria of interest called *Prony filtering* [2].

Therefore, in an effort to increase the accuracy and efficiency in determining and interpreting the attenuation of a seismic signal, we propose a new method for directly estimating the attenuation parameter from seismic data and correlating it with the *Q* factor based on the Prony spectral decomposition.

This technique can be an additional alternative to traditional methods, such as, for example, the spectral ratio method, when constructing new mathematical formulas for estimating the *Q* factor. Among the advantages of this approach is the direct determination of the attenuation parameter in the process of signal decomposition and the high degree of resolution obtained using the Prony spectral decomposition.

Signal modeling is essential for studying the developed methodology since the parameters used for the simulated signals are known and can be directly compared with the calculated ones, which makes it possible to check their effectiveness with accuracy. It does not occur with field seismic data, where the task is precisely to identify the parameters that characterize them and are associated with the analyzed medium.

Furthermore, to test the method, various types of data were simulated, such as damped sinusoids with the addition of time shifts and random noise, aiming to simulate conditions closer to real ones, as well as viscoacoustic modeling of seismic traces with different values of the *Q* factor using the Berlage wavelet for different center frequencies. In addition, the methodology was applied to experimental ultrasonic data obtained from laboratory measurements of elastic petrophysics, performed by varying the confinement pressures of samples of carbonate rock plugs.

The results demonstrate the capabilities of this method, which provides good accuracy in determining the *Q* factor for both simulated and field data compared to the conventional spectral ratio method.

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[2] Mitrofanov, G. M. and Priimenko, V. I. (2013). Prony filtering of seismic data: mathematical and physical modelling. Rev. Bras. Geofís. 31(1), 151-168.