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Instantaneous frequency using fractional derivatives of gpr data

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Fractional calculi have attracted the attention of some scientist in applied geophysics. Most of applications have seen on the potential field in order to detect edges. In this study, we calculated instantaneous frequency using the fractional time derivative of a ground penetrating data (GPR) set to detect thin layers. It is well-known that the fractional derivative of a time series can be calculated various methods such as Grünwald-Letnikov, Caputo, Rieman-Liouville. Here, we used Grunwald-Letnikov method to estimate the fractional time derivative of a GPR trace.

Attributes such as amplitude, instantaneous frequency and instantaneous phase are commonly used in seismic industry for highlighting anomalies in the data. Seismic traces are depending on time, amplitude, frequency and attenuation as GPR traces. To generate a complex GPR trace, we used the same method as in seismic. Thus, using the Hilbert transform of a GPR trace, one can have a complex GPR trace. Then, we can calculate some attributes.

In this study, we chose a three-layered earth as a synthetic model with a thin layer thicknesses varies 5, 7 and 10 cm, respectively. To generate a synthetic model, we used 2D (2-Dimensional) FDTD (Finite Difference Time Domain) method. Further, the response of a wedge model was also analyzed to investigate a thin layer resolution. As a source, we used a 300 MHz Ricker wavelet for all synthetic models.

As a conclusion, based on our numerical examples we observed that instantaneous frequency calculated on 0.99th time derivative (FIF) and standard instantaneous frequencies are almost the same. However, there are increasing phase shift between FIF and SIF upon using the time derivative of 0.1, 0.2, 03, etc. and up to 0.89. Therefore, FIF gives a phase shift of a trace. If we try to determine the precise thickness and location of a layer, in this case better to use SIF or FIF on 0.99th derivative rather than the time derivative of 0.1, 0.2, 03, etc. and up to 0.89.