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# High-Frequency Full-Waveform Inversion: Just How High Should You Go?

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## Summary

We pose the question, "how high a frequency should you go to in FWI?" The answer depends on your objective: the traditional processes of imaging, reservoir characterization, and interpretation, or as a potential complete replacement for these. In this paper we discuss and demonstrate the impact of the maximum frequency in the FWI velocity model on these processes, using data sets from the North and Norwegian Seas.

**Abstract**

Full-waveform inversion (FWI) has proven itself as a vital tool for velocity model building using seismic data. In recent years, the geophysical community has made good progress in developing FWI to overcome some limitations, for example, to handle cycle skipping, to better use reflection energy, to include more physics in the inversion algorithms, and to push towards ever higher frequencies.

We pose the question, "how high a frequency should you go to in FWI?" The answer depends on your objective: the traditional processes of imaging, reservoir characterization, and interpretation, or as a potential complete replacement for these. In this paper we discuss and demonstrate the impact of the maximum frequency in the FWI velocity model on these processes, using data sets from the North and Norwegian Seas. In all but the most pathological of cases, the resulting seismic image is only improved by the FWI model up to ~15-20 Hz. Beyond this, the image often does not change dramatically, even with high-end imaging algorithms such as reverse time migration that capture the extra resolution. A similar behavior is also observed when using an FWI model as the low-frequency background trend in seismic impedance inversion – it is of benefit up to ~15-20 Hz again, but does not alter the final results very much if a higher frequency FWI model is used.

The long-term goal of FWI is to invert the whole seismic bandwidth, naturally handling multiples and illumination compensation as part of the process, and replace these traditional steps with the inverted FWI Earth model. To do this completely for real data will require visco-elastic FWI. However, most industry applications are some form of acoustic FWI due to compute and memory restrictions (the elastic case being approximately two orders of magnitude more demanding than the acoustic case, with acoustic still a computational challenge today, compared to other seismic processing steps).

Therefore, assuming a "silver bullet" doesn't come along to address these problems, we propose that, with today's hardware capabilities, in many exploration basins around the world it is better to do the best possible physics to ~15 Hz (including anisotropy, attenuation, and possibly elasticity), with subsequent imaging for reflectivity, and impedance inversion for characterizing AVO. Additionally, we argue that the interpretational aspects of the FWI model are more valuable when we have confidence that the underlying physics used in the inversion better represents the complexity of the real Earth. Sometimes acoustic, isotropic physics may be enough, but sometimes not, and, as we become more discerning practitioners of FWI, this seems less and less likely to be the case.