The estimation of source wavelet is important for successful implementation of full-waveform inversion (FWI). Many FWI algorithms estimate the source signature iteratively in the inversion process. In this paper, a source-independent method is adopted with a data calibration process. Furthermore, the gradient-based methods for FWI suffer from slow local convergence rate. A Hessian-free (HF) Gauss-Newton method is implemented in this research by solving the Newton system with a conjugate-gradient (CG) method. With the source-independent strategy, the Gauss-Newton Hessian is also modified. We demonstrate with numerical examples that the HF Gauss-Newton method with the modified Hessian can improve the convergence rate and reduce the computational burden.

The FWI misfit function with source weight is expressed as:

$$\phi(m,s) = \frac{1}{2} \sum_{x_1} \sum_{x_2} \sum_{\omega} \|d_{obs}(x_1, x_2, \omega) - s(x_1, \omega) d_{syn}(m, x_1, x_2, \omega)\|^2$$

where the source weight is obtained as:

$$s(x_1, \omega) = \sum_{x_2} d_{obs}(x_1, x_2, \omega) d_{syn}^*(x_1, x_2, \omega) \sum_{x_2} d_{syn}(x_1, x_2, \omega) d_{syn}^*(x_1, x_2, \omega)$$

The Jacobian matrix is expressed as:

$$\tilde{J}(x_1, x_2, \omega) = s(x_1, \omega) \frac{\partial d_{syn}(x_1, x_2, \omega)}{\partial m} + \frac{\partial s}{\partial m} d_{syn}(x_1, x_2, \omega)$$

The gradient and Hessian can be written as:

$$g = \tilde{J}^* \Delta d, \tilde{H}_d = \tilde{J}^* \tilde{J}$$

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