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Temporal variations in magnetic signals generated by the piezomagnetic effect for dislocation sources in a uniform medium

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Fault ruptures in the Earth's crust generate both elastic and electromagnetic (EM) waves. If the corresponding EM signals can be observed, then earthquakes could be detected before the first seismic waves arrive. Few reports have been published on EM phenomena that precede seismic wave arrivals; however, because geomagnetic observations are sparse compared with seismic and geodetic observations, it is possible that such phenomena have not been reported simply because of insufficient opportunities for observation. Therefore, theoretical approaches are required, along with efforts to refine observations.

In this study, I consider the piezomagnetic effect as a mechanism that converts elastic waves to EM energy, and I derive analytical formulas for the conversion process. The situation considered in this study is a whole-space model, in which elastic and EM properties are uniform and isotropic. In this situation, the governing equations of the elastic and EM fields, combined with the piezomagnetic constitutive law, can be solved analytically in the time domain by ignoring the displacement current term. Using the derived formulas, numerical examples are investigated, and the corresponding characteristics of the expected magnetic signals are resolved. I show that temporal variations in the magnetic field depend strongly on the electrical conductivity of the medium, meaning that precise detection of signals generated by the piezomagnetic effect is generally difficult. Expected amplitudes of piezomagnetic signals are estimated to be no larger than 0.3 nT for earthquakes with a moment magnitude of ≥ 7.0 at a source distance of 25 km; however, this conclusion may not extend to the detection of real earthquakes, because piezomagnetic stress sensitivity is currently poorly constrained.