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In Situ Calculation of Spaceflight Magnetometer Coupling Coefficients for Interference Removal using RAMEN Gradiometry Algorithm

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High-fidelity in situ magnetic field measurements of celestial objects and the solar wind are often limited by spacecraft-generated interference, known as stray magnetic fields. These fields, generated by currents from spacecraft subsystems, are frequently several times stronger than the ambient magnetic field signals of interest. To mitigate this, strict magnetic cleanliness, long mechanical booms, and at least two magnetometers are typically necessary to eliminate the spacecraft-generated magnetic interference. When two magnetometers are placed collinearly on a boom, gradiometry can be performed by modeling the spacecraft's field as a dipole and subtracting it from the magnetometer measurements. However, this technique requires careful preflight characterization of the spacecraft's magnetic field to determine the dipole coupling coefficients and sufficient boom length. This process is time-intensive, costly, and prone to error due to the changing nature of a spacecraft magnetic field environment in operation. We present a novel method for in situ calculation of the gradiometric coupling coefficients, called the Reduction Algorithm for Magnetometer Electromagnetic Noise (RAMEN). RAMEN utilizes single-source point analysis and the time-frequency content of the magnetometer signals to identify stray magnetic field signals and calculate the gradiometric coupling coefficients. Through two Monte Carlo simulations, we demonstrate that the RAMEN gradiometry algorithm matches gradiometry with preflight coupling coefficient estimation. Additionally, we apply the RAMEN algorithm to noisy magnetometer data from the Venus Express spacecraft to demonstrate its use in situ. The RAMEN method enhances the fidelity of spaceborne magnetic field observations using gradiometry and reduces the burden of arduous preflight spacecraft magnetic characterization.