

SuperDARN・地上磁力計・あらせ衛星による 1/4 波長磁力線共鳴振動の共役観測

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Quarter-Wave Resonances: Coordinated Observations by SuperDARN, Magnetometers, and Arase

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Between 00:00 and 02:00 UT on 23 November 2022, during exceptionally quiet geomagnetic conditions, a clear ultra-low frequency (ULF) wave in the Pc5 band (~2.4 mHz) was observed in the duskside subauroral region by two Canadian SuperDARN radars. The wave showed a periodic Doppler velocity signature resembling a "caterpillar" with northeastward (anti-sunward) propagation and an azimuthal wave number of ~12. Ground magnetometer data revealed latitude variations in amplitude and phase consistent with field line resonance (FLR), peaking near 66° magnetic latitude.

The Arase satellite, whose ionospheric footprint crossed the caterpillar wave region, detected toroidal oscillations in both electric and magnetic fields at magnetically conjugate locations in the inner magnetosphere. These oscillations showed strong coherence with ground observations. Importantly, the electric field led the magnetic field by ~45° in phase. This phase relationship suggests the wave included both a standing mode and a propagating component that carried energy toward the northern ionosphere.

Electron densities of ~21-25 cm⁻³ at the satellite location were inferred from the upper hybrid resonance (UHR) frequency obtained by PWE/HFA. From this density, the resonance frequency of a fundamental half-wave mode was estimated to be ~3.9 mHz, higher than the observed frequency (~2.4 mHz). This difference suggests the observed wave may instead be a quarter-wave mode, which typically occurs at 1.5-1.7 times lower frequency than the half-wave.

Numerical simulations using a 2.5-dimensional dipole magnetosphere model also reproduce quarter-wave characteristics. Previous studies have shown that quarter waves are favored during quiet geomagnetic conditions and when ionospheric Pedersen conductance differs by a factor of five or more between hemispheres. Both conditions were satisfied in this event, supporting the quarter-wave interpretation.