Upper hybrid mode and ESCH waves in the auroral ionosphere: A possible source of MF auroral radio emissions

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The Earth's auroral region is an active radio source at frequencies from a few hertz to several megahertz. In the MF (medium frequency) range, THR (terrestrial hectometric radiation) is observed in the topside ionosphere [e.g. *Oya et al.*, 1985]. At the ground level, auroral roar and MF burst were discovered by *Kellogg and Monson* [1979, 1984] and *Weatherwax et al.* [1994] in the northern Canada. It is interpreted that the origin of both emissions is the upper hybrid waves generated in the ionosphere by auroral electrons, and they should be converted to the electromagnetic L-O mode waves. Some theoretical studies [e.g. *Weatherwax et al.* , 2002] have proposed that MF burst which has a broad band spectrum is generated at an altitude of few hundred kilometers over a wide altitude range, while auroral roar is excited in altitudes where a condition of $f_{UH} \sim nf_{ce}$ (n=2, 3) is met, which leads to its narrow band spectrum. However, the characteristics of the quasi-electrostatic waves in the polar ionosphere as an origin of auroral roar, MF burst and THR remains unclear. In this study, we investigate these waves associated with auroral electron precipitation using Akebono satellite data, and compare with our ground-based observation of auroral roar and MF burst.

The in-situ observation by the Akebono satellite proves the presence of mode conversion process from upper hybrid waves into L-O mode waves: The weak electromagnetic THR emissions connecting to relatively strong and broadband upper hybrid mode waves in a frequency-time spectrogram were detected under the matching condition of $f_{UH} \sim 2f_{ce}$ in an altitude of several thousands of kilometers. This observation, although in the topside ionosphere, supports the scenario that auroral roar originates from the upper hybrid waves which is enhanced when f_{UH} is nearly equal to nf_{ce} and mode-converted to L-O electromagnetic mode.

The Akebono satellite observation also shows that enhancement in a frequency range of upper hybrid mode in the auroral ionosphere is composed of various and complicated spectral features: either of both narrowband and broadband. Intriguingly, the emission is enhanced in the form of ESCH (electrostatic electron cyclotron harmonics) waves in addition to under the condition of $f_{UH} \sim nf_{ce}$. The auroral roar detected on May 23, 2007 in Iceland appeared in the unique emission frequency range which cannot be expected with the above proposed mechanism. This observation suggests that ESCH wave generated by plasma instability near $(n+1/2)f_{ce}$ is converted into L-O mode via upper hybrid wave, and reaches to the ground level. The Akebono data indicates the presence of ESCH wave in the polar ionosphere.