§7. Hybrid Alfvén Resonant Mode Generation in the Magnetosphere-ionosphere Coupling System

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Feedback unstable Alfvén waves involving global field-line oscillations and the ionospheric Alfvén resonator (IAR) were comprehensively studied to clarify their properties of frequency dispersion, growth rate, and eigenfunctions. As an extended study of our previous works,[1)] linear eigenmodes of ionospheric feedback instability in the dipole magnetic field (B_0) geometry were analyzed by considering the ionospheric and magnetospheric resonant cavities of the Alfvén velocity (v_{A}). The two-field reduced magnetohydrodynamic model,

$$\partial_t \omega + \boldsymbol{v}_0 \cdot \boldsymbol{\nabla}_\perp \omega = v_{\mathrm{A}}^2 \nabla_\parallel j_\parallel \qquad (1)$$

$$\partial_t \psi + \boldsymbol{v}_0 \cdot \boldsymbol{\nabla}_\perp \psi + \frac{1}{B_0} \nabla_\parallel B_0 \phi = 0, \qquad (2)$$

is used to describe shear Alfvén wave dynamics, associated with auroral arcs, in a strongly non-uniform magnetic flux tube; see our paper[1)] for definition of these variables.

These equations are coupled with the two-fluid equations in the ionosphere as,

$$\partial_t n_{\mathrm{e}} + \boldsymbol{v}_0 \cdot \boldsymbol{\nabla}_\perp n_{\mathrm{e}} = j_\parallel - R n_{\mathrm{e}} \qquad (3)$$

$$-\alpha \nabla_\perp^2 \phi + (\mu_{\mathrm{P}} \boldsymbol{E}_0 - \boldsymbol{v}_0) \cdot \boldsymbol{\nabla}_\perp n_{\mathrm{e}} = D \nabla_\perp^2 n_{\mathrm{e}} - j_\parallel, \qquad (4)$$

yielding the linear dispersion relation for feedback instability; see our paper[1)] for definition of these variables. Equations (1)–(4) are solved to obtain the eigenfrequency and eigenfunctions of Alfvén waves shown in Figs. 1 and 2.

This study[2)] discovered that a new mode called here the hybrid Alfvén resonant (HAR) mode can be destabilized in the magnetosphere-ionosphere coupling system with a realistic v_{A}. The HAR mode found in a high frequency range over 0.3 Hz is caused by coupling of IAR modes (0.5, 1 Hz, ...) with strong dispersion and field line resonances (FLR). The harmonic relation of HAR eigenfrequencies is characterized by a constant frequency shift from those of IAR modes. The three modes (FLR, IAR, and HAR) are robustly found even if effects of two-fluid process and ionospheric collision are taken into account, and thus are anticipated to be detected by magnetic field observations in auroral and polar-cap regions.

1) Hiraki Y., and T.-H. Watanabe: J. Geophys. Res. **116** (2011) A11220.

2) Hiraki Y., and T.-H. Watanabe: Phys. Plasmas **19** (2012) 102904.

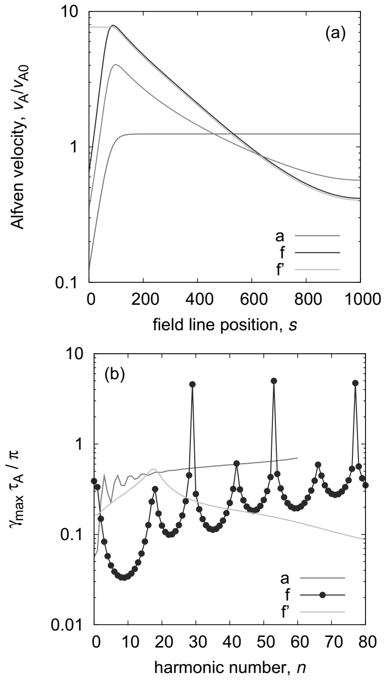

Fig. 1: (a) Alfvén velocity profiles $v_{\mathrm{A}}(s)$ used in this analysis. (b) The maximum growth rate $\gamma_{\max}(n)\tau_{\mathrm{A}}/\pi$ as a function of harmonic number n; $\gamma \equiv \mathrm{Im}(\Omega)$ with the Alfvén transit time τ_{A}.

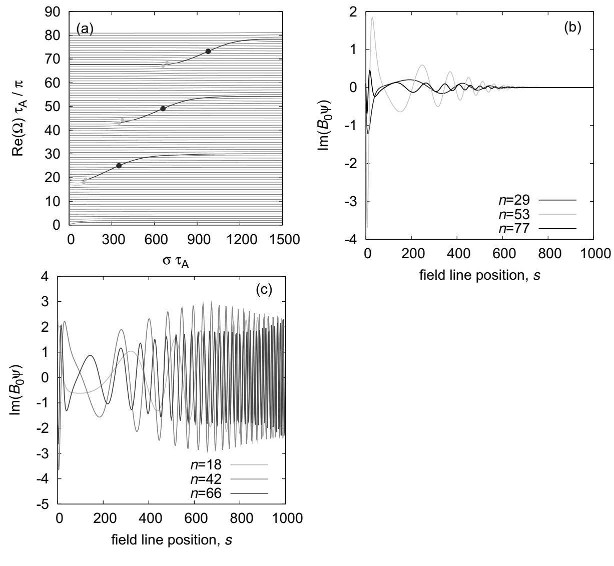

Fig. 2: (a) Real part of eigenfrequency $\mathrm{Re}(\Omega)\tau_{\mathrm{A}}/\pi$ as a function of electric drift frequency σ for v_{A} profile f in Fig. 1. The harmonics n = 0–80 are shown. Shown are eigenfunctions $\mathrm{Im}(B_0\psi)$ of (b) IAR (n = 29, 53, and 77) and (c) HAR (n = 18, 42, and 66) modes providing $\gamma_{\max}(n)$.