Field line resonance and cavity modes

According to ideal MHD wave theory, a plasma can support two basic wave types, i.e., the magnetosonic wave and the Alfvén wave. In the theory, standing Alfvén waves can be excited on geomagnetic field lines, forming so called field line resonances (FLR). Boundary conditions at the ionospheric ends of the field lines cause the parallel wave number k_T to be quantized as $k_T = n\ pi / l$, where l is the length of the field line. Hence the frequency w is also quantized as $w = k_T v_A$, where v_A is the Alfvén velocity on the field line. These geomagnetic standing waves are often considered to be analogous to the waves on a violin string (Bellan, 1996).

The standard model for FLR excitation calls for a compressional wave mode trapped in a cavity bounded on the inside by the resonant field line, on the outside by the magnetopause, and on the ends by the polar ionospheres (Kivelson and Southwood, 1985, 1986). This box model has been extended to a waveguide model by allowing the azimuthal direction in the cylindrical geometry to become open-ended (Samson et al., 1992; note that this waveguide has nothing to do with the ionospheric waveguide). Nightside auroral Pc 5 pulsations quantized at 0.9, 1.3, 1.95, 2.6, and 3.3 mHz have been interpreted as FLR excited by quantized compressional modes (Ruohoniemi et al, 1991; Samson et al., 1991). See also Ziesolleck et al. (1996).

Bellan (1996) has argued against the whole FLR concept on theoretical grounds. Because the ideal MHD ignores electron inertia, FLRs are only an artifact of the too simple theory, and they cannot be found when using the Maxwell - Lorentz system of equations.

References

- Bellan, P. M., Mode conversion into non-MHD waves at the Alfvén layer: The case against the field line resonance concept, *J. Geophys. Res.*, **101**, 24887-24898, 1996.
- Bellan, P. M., Now model for ULF Pc5 pulsations: Alfvén cones, *Geophys. Res. Lett.*, **23**, 1717-1720, 1996.
- Kivelson, M. G., and D. J. Southwood, Resonant ULF waves: A new interpretation, *Geophys. Res. Lett.*, **12**, 49-, 1985.
- Kivelson, M. G., and D. J. Southwood, Coupling of global magnetospheric MHD eigenmodes to field line resonances, *J. Geophys. Res.*, **91**, 4345-4351, 1986.
- Ruohoniemi, J. M., R. A. Greenwald, K. B. Baker, and J. C. Samson, HF radar observations of Pc 5 field line resonances in the midnight / early morning MLT sector, *J. Geophys. Res.*, **96**, 15697-, 1991.
- Samson, J. C., R. A. Greenwald, J. M. Ruohoniemi, T. J. Hughes, and D. D. Wallis, Magnetometer and radar observations of magnetohydrodynamic cavity modes in the Earth's magnetosphere, *Can. J. Phys.*, **69**, 929-, 1991.
- Samson, J. C., B. G. Harrold, J. M. Ruohoniemi, J. M., R. A. Greenwald, and A. D. M. Walker, Fieldline resonance associated with MHD waveguides in the magnetosphere, *Geophys. Res. Lett.*, **19**, 441-, 1992.
- Ziesolleck, C. W. S., Q. Feng, and D. R. McDiarmid, Pc 5 ULF waves observed simultaneously by GOES 7 and the CANOPUS magnetometer array, *J. Geophys. Res.*, **101**, 5021-5033, 1996.