APPENDIX

Stochastic Growth of Waves Over Earth's Polar Cap

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Abstract. Bursty waves with widely varying electric fields persist over a wide range of altitudes ~ 2-7 R_E at polar cap latitudes in Earth's inner magnetosphere. These "PF" waves have frequencies near expected values of the electron plasma frequency (PF), well below the electron gyrofrequency, and are believed to be generated by electron beams. Here it is demonstrated that stochastic growth theory (SGT) can account well for the detailed field statistics of the archetypal PF wave event, by showing that the observed distributions P(log E) of envelope electric fields E are well fitted by the lognormal function predicted by SGT. Weak evidence exists that a nonlinear wave process coexists with stochastic growth physics at large fields $\geq$ 1 mV/m, based on fits of the observed P(log E) distribution to the SGT prediction that includes a nonlinear process at high fields and on the discovery of a class of low frequency waves that may be produced by nonlinear decay of PF waves. An analytic model is developed for why the waves evolve to an SGT state, based on waves driven by an electron beam in MHD density turbulence and the development of fluctuations in the electron beam due to wave growth occurring in localized regions. The model is viable for the polar cap plasma parameters considered, predicting that the wave burstiness should be of order that observed and that the beam fluctuations should have timescales ~ 10 ms that are below current detection capabilities. SGT thus accounts well for the burstiness and wave statistics, as well as the persistence of the waves and driving distribution. The consistency of the PF wave statistics with SGT also implies the presence of local electron beams over much of the polar cap, whose source is currently unknown. This application brings to 5 the number of contexts in which SGT applies, suggesting that SGT is widely applicable in space plasmas.

Project Summary:

The objective of this proposal was to conduct a comprehensive observational and theoretical investigation, including 2-D numerical simulations of emissions that occur near f_p and 2 f_p as observed by the Dynamics Explorer 1 (DE 1) spacecraft in the mid-altitude polar magnetosphere. Electrostatic electron plasma waves (or Langmuir waves) and associated electromagnetic (EM) radiation near f_p and 2 f_p have previously been observed associated with the Earth's foreshock and in coronal/solar wind type II and III solar radio bursts. The observations of similar emissions in the terrestrial polar magnetosphere have not been previously reported and are important for a better understanding of the range of generation processes. We have been cataloging the location, electric and magnetic intensity, polarization, bandwidth, etc. of the emissions. The theoretical analysis included linear and nonlinear plasma theory. The goal was to fully describe the generation processes for both the f_p (PF component) and $2f_p$ (H component) emissions. Although this goal was not completely accomplished, we have made significant advances in our understanding of these emissions.

Work Accomplished:

As a result of funding for this project we have identified 2 f_p emissions in the Dynamics Explorer plasma wave data and conducted of survey of the emission. These results were reported in Cairns and Menietti [1997] and Menietti et al. [1998].

To date we have completed a study of the measurement of number density of a plasma using the enhancement of the ratio E/B for z-mode radio waves near the plasma frequency. This work has appeared in *Physical Review Letters* as sited below.

We have collected data from the Dynamics Explorer spacecraft to determine if the stochastic growth theory [Cairns and Robinson, *Geophys Res. Lett.*, *24*, 369, 1997] can explain the HF emissions. This theory predicts that a plot of log(P) versus log(E) should be parabolic in shape, where P is the power spectral density of the waves and E is the electric field strength. In this study, we are measuring the absolute intensities of the observations of HF emissions for a number of cases. The work is undergoing review in the *Journal of Geophysical Research.* An abstract of this paper is included in the Appendix.

Publications and submissions resulting from this study are listed below:

Publications

Cairns, I. H. and J. D. Menietti, Radiation near 2fp and intensified emissions near fp in the dayside and nightside auroral region and polar cap, *J. Geophys. Res.*, *102*, 4787, 1997.

Menietti, J. D., I. H. Cairns, C. W. Piker, and T. F. Averkamp, Statistical study of emissions near fp and 2fp in the dayside and nightside auroral region and polar cap, *J. Geophys. Res.*, *103*, 14,295, 1998.

Cairns, I. H., Measurement of the plasma density using the natural intensification of z-mode waves at the electron plasma frequency, *Physical Review Letters*, *82*, 564, 1999.

Gary, S. P. and I. H. Cairns, Electron temperature anisotropy instabilities: Whistler, z-mode, and electrostatic, *J. Geophys. Res.*, *104*, 19,835, 1999.

Cairns, I. H., J. D. Menietti, S. Peter Gary, J. D. Dorelli, and P. A. Robinson, Stochastic Growth of Waves Over Earth's polar cap, submitted to *J. Geophys. Res.*, 2001.