THE ELECTRON CYCLOTRON MASER INSTABILITY: AN AURORAL WAVE-PARTICLE INTERACTION MECHANISM

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ABSTRACT

The generation and propagation of cyclotron maser emissions produced by a primary electron half-shell distribution with a characteristic energy of 2–10 keV are investigated using 2-1/2 dimensional particle simulation models. Of the two polarization states with E perpendicular to B, that with electric field along the spacecraft trajectory is predicted to be dominant for intense AKR emissions within the source region. These predictions are confirmed by FAST observations.

INTRODUCTION

The properties of the electron-cyclotron maser radiation produced in the auroral kilometric radiation (AKR) source cavity are investigated by means of two-dimensional particle-in-cell simulations and observations made by the Fast Auroral SnapshoT (FAST) Explorer. The simulations assume a population of primary auroral electrons with a downgoing shell distribution. Two different simulation models are considered: (1) a meridional-plane model where the electron distribution is continually injected at the high altitude boundary, and (2) a longitudinal-plane model where initial-value simulations are used to study the maser propagation perpendicular to the magnetic field.

SIMULATION RESULTS

In the meridional-plane model the maser radiation builds up very rapidly with decreasing altitude, and bursts of radiation with time scales of the order of 0.5 ms are produced at only 5–6 km below the injection level. Consistent with the FAST observations, the radiation propagates nearly perpendicular to the magnetic field. Reflections of the radiation at density enhancements within the source cavity are found to be insignificant. The longitudinal-plane results indicate that the maser radiation component incident normally on the cavity boundary (with “across track” E polarization) tends to leak out of the cavity via conversion to the Z mode and absorption by the ambient cold plasma. This destroys the coherency of this component. In contrast, the component propagating in the longitudinal direction (with “along track” E polarization) is free to grow along an extended path length.

FAST OBSERVATIONS

It is possible to determine all three components of the electric field for intervals with high speed burst memory (HSBM) data. Of the two E components perpendicular to B, the along track component is comparable to, or frequently considerably stronger than, the across track component. This dominance of the along track orientation is particularly apparent for the stronger intensity AKR cases. Fig. 1 shows the power in the three E polarizations as a function of frequency for orbit 1907. The HSBM data occur near the equatorward edge of a $\sim$36 km wide cavity. The peak power occurs at $\approx$435 kHz; here the along track polarization (green curve) is a factor of $\sim$100 greater than the across track polarization (red curve). No examples were found in the FAST data where the across track polarization was larger. These results indicate that the AKR emissions do not form a standing wave structure between the cavity boundaries.

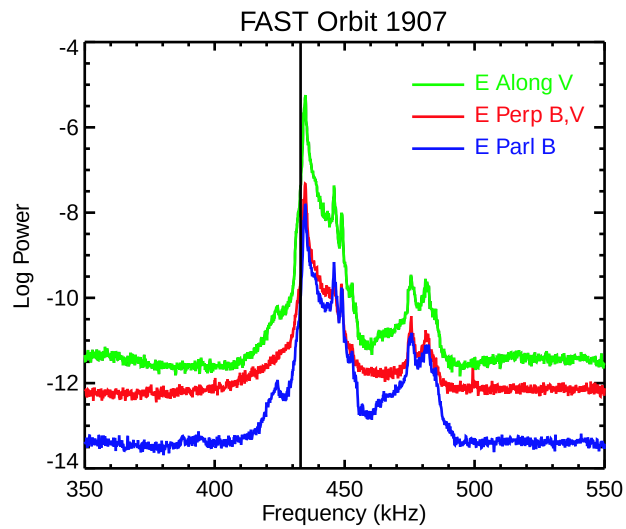

Fig. 1. Power spectra for the three electric field components as determined from a FAST crossing of the AKR source region on orbit 1907. The two perpendicular field components have been projected along directions parallel to the spacecraft trajectory and perpendicular to both B and the trajectory. The vertical solid line indicates the (nonrelativistic) electron cyclotron frequency.