Doppler Broadening of Electron Cyclotron Waves in the Ionosphere

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Abstract

Electron-cyclotron waves (ECWs) were transmitted over emitter-receiver separations of ~100m in the rocket experiment OEDIPUS-C. Propagation effects imposed considerable variety on the received ECW pulse shapes. Hot-plasma theoretical signal delays agree with observations for some frequencies in the ECW propagation band. But the observed pulse spectra extend over a range of several kilohertz above and below the gyrofrequency harmonic, a much broader bandwidth than theoretically predicted . This broadening is interpreted as a Doppler effect caused by payload motion and backscatter of the ECWs, by pre-existing field-aligned density irregularities and/or by induced waves.

Text

Active wave experiments have produced much evidence for the existence in manmade and natural magnetoplasmas of ECWs, also called electron Bernstein waves. Data from laboratory experiments, spaceborne sounders and ionospheric heaters clearly show the presence and/or agency of such waves. Topside sounders directly stimulate echoing ECWs. Sounders and ionospheric heaters nonlinearly produce waves at frequencies that depend on harmonics of the electron cyclotron frequency f_c**.** What is notable in the literature is the rarity of reports of ECWs spontaneously generated in the ionospheric magnetoplasma. The OEDIPUS-C(OC) experiment has uncovered a feature of ECW spectra that could contribute to the difficulty of direct observation of spontaneous ECWs.

Ordinary(L,O)- and extraordinary(R,X)- mode cold-plasma waves and electrostatic electron cyclotron waves at harmonics nf_c were simultaneously transmitted over field-aligned emitter-receiver separations of hundreds of meters in the active two-point OC experiment. ECW harmonics n = 2, 3, and 4 were observed in a frequency range between 2.4 and 5.4 MHz in circumstances where the plasma frequency was about one third of f_c. The 300-µs rectangular current pulses into the emitting antenna produced smoothly maintained O+X pulses at the receiver throughout the experiment. In contrast, the transmitted ECW pulses exhibited considerable variety in both the time and frequency domains. The contrast implies that the ECW fluctuations arose during propagation, not from effects of wave injection or detection.

A full hot-plasma dispersion relation has been applied to ray-tracing investigations to identify the rays that could connect the emitter and receiver in a smoothly varying model of the ionospheric magnetoplasma. Theoretical signal delays agree with observations for some frequencies within the $2f_c$ propagation band, between $2f_c$ and the associated Q-resonance frequency f_{Q2}. But the observed pulse spectra extend over a range of several kilohertz above and below nf_c, a much broader bandwidth than that predicted by the hot-plasma theory. This broadening is interpreted as a Doppler effect caused by payload motion and backscatter of the ECWs, either by pre-existing field-aligned density irregularities typical of the auroral topside ionosphere, or by induced waves. Thus the Doppler broadening of the narrow ECW bandwidth, nf_c to f_{Qn}, may tend to make the ECW harmonic bands more diffuse, and hence less easily seen, in spectrograms.