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Properties of harmonic electron cyclotron waves in the low-density auroral ionosphere

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Bernstein or electron-cyclotron waves (ECWs) were transmitted over magnetic-field-aligned separations of hundreds of metres in the OEDIPUS-C (OC) sounding-rocket experiment. Signals were observed at harmonic frequencies mfc of the electron cyclotron frequency fc, where m was 2, 3, and 4, fc $\approx$ 1.3 MHz, and the electron plasma frequency was less than half of fc. Analysis of the data has revealed peculiar properties of these waves in the areas of geometric optics and dipole radiation:

1) For the plasma conditions local to the OC experiment, solutions of the full electromagnetic hot-plasma dispersion relation lead to refractive index surfaces n(θ) that have the shape of thin annuli. The wave vector angle θ for undamped propagation is found to be confined to 90.0º $\pm$0.1º with respect to the axis of the terrestrial magnetic field B. A consequence of such n(θ) shapes is that undamped ray directions can exist from perpendicular to B to within a few degrees of the B axis. Rays traced for 2fc radiation from a point for all starting θ are restricted to a narrow tube of cross-B extent of about 50 m in the OC experiment circumstances.

2) The electric-field E radiation patterns from a dipole antenna were evaluated for ECWs at 2fc using solutions of the inhomogeneous Helmholtz wave equation with the above-mentioned hot-plasma dispersion relation. The result is an unusual tubular shape for the radial component of E, whose magnitudes are much greater than those of the other two components.

Thus, ray optics and antenna patterns both predict B-aligned flow of energy of ECW harmonics in the OC experiment conditions. Theoretical B-alignment is consistent with the strong mfc transmission achieved with the B-aligned geometry of the OC emitter-receiver pair. The field alignment properties of artificial ECWs may help to explain the absence at ionospheric altitudes of the observation of spontaneous emissions in this electrostatic wave mode.