Emission and Reception of Bernstein Waves in the OEDIPUS-C Experiment

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Abstract

The amplitudes of electron-cyclotron waves (ECWs, Bernstein waves) transmitted near the second harmonic of the electron gyrofrequency during the OEDIPUS-C two-point experiment were computed under particular assumptions. The current in the emitting dipole was determined by the impedance for simultaneously emitted cold-plasma ordinary- and extraordinary-mode waves. The Bernstein electric-field radiation patterns of the emitting dipole were based on the dispersion surfaces from the hot-plasma theory for tenuous magnetoplasmas. These patterns were found to have maxima close to the magnetic field axis. Computations of the receiving-dipole voltages were based on an assumption about the dipole effective length.

Text

Electron cyclotron waves (ECWs, Bernstein waves) were transmitted over magnetic-field-aligned separations of hundreds of metres in the OEDIPUS-C (OC) sounding-rocket experiment [1]. Signals were observed at harmonic frequencies mf_{ce} of the electron cyclotron frequency f_{ce}, where m was 2, 3, and 4, $f_{ce} \approx 1.3$ MHz, and the electron plasma frequency was less than half of f_{ce}. The signals transmitted at $2f_{ce}$ have been analyzed using particular physical assumptions about these waves in the areas of active-dipole impedance, dipole radiation and receiving-dipole effective length.

The observations in question were made with a synchronized frequency sweep of the emitting and receiving parts of the payload. At each 50-kHz step of the sweep, the emitter produced a 300-microsecond pulse, while the receiver bandwidth centre was tuned to the pulse carrier frequency. As mentioned in [1] in connection with its Figure 5, the comparatively strong pulses received in the cold-plasma ordinary (O) and extraordinary (X) modes transmitted in the frequency channel 50 kHz below the channel containing $2f_{ce}$ had negligible amplitude differences from the O,X pulses transmitted in the $2f_{ce}$ channel. From this it was deduced that the ECW contribution to the total impedance of the emitting dipole was negligible. Hence, the current in the emitting dipole employed in the dipole ECW radiation theory was that determined by the application of the vacuum theory for dipoles, since the emitted frequencies near $2f_{ce} \approx 2.6$ MHz were well above the O- and X-mode cutoff frequencies.

For the plasma conditions local to the OC payload, solutions of the full electromagnetic hot-plasma dispersion relation lead to refractive index surfaces $n(\theta)$ that have the shape of thin annuli. θ is the angle between the wave vector and the terrestrial magnetic field **B.** Angle θ for undamped propagation is found to be confined to 90.0º ±0.1º with respect to **B**. A consequence of such $n(\theta)$ shapes is that undamped ray directions can exist from perpendicular to **B** to within a few degrees of the **B** axis. Rays traced for $2f_{ce}$ 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.

The electric-field **E** radiation patterns from the emitting dipole antennas were evaluated for ECWs at $2f_{ce}$ 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 magnitude is much greater than that 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 mf_{ce} transmission achieved with the **B**-aligned geometry of the OC emitter-receiver pair.

At the receiving subpayload, the effective length of the receiving dipoles was put equal to their physical length, L. The decision to use the value of L, and not the typical value from short dipole theory of $L/2$, was influenced by the possibility that effective lengths of receiving dipoles may be significantly greater than $L/2$ for electrostatic waves having group velocities almost perpendicular to their wave vectors [2,3].

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References

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