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Direct Comparison of Whistler Mode Radiation Between an Electric Dipole and Loop Antenna in a Laboratory Plasma

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High energy electrons from either solar wind or human activity become trapped inside the Van Allen radiation belts or create an artificial radiation belt that can persist for long periods of time. Spacecraft flying through these belts are susceptible to damage from these trapped electrons. Whistler waves are known to precipitate electrons into the atmosphere. A proposed solution is using spacecraft to carry compact electron beams or antennas which radiate whistlers to remediate these trapped electrons. This remediation effort has picked up momentum with knowledge gained from recent space missions such as the Van Allen Probe spacecraft which collected data on electron loss mechanisms. Additionally, the recently completed Demonstration and Science Experiment (DSX) satellite conducted experiments on the efficiency of injecting very low frequency (VFL) waves in space with their novel 82-meter tip to tip electric dipole antenna. Based on these missions and existing laboratory studies [1], there is still no clear candidate as the best generator of whistler waves for the purposes of a spacecraft-based radiation belt remediation.

We report results of a laboratory plasma experiment comparing the efficiency of exciting whistler waves by an electric dipole and loop antennas. For the first time, the complex impedance on a loop antenna has been directly measured by measuring the voltage and current directly on the antenna loop. A significant decrease in the real part of the impedance is measured as the plasma density is decreased. To support practical space-based deployment, we investigate how the antenna size relative to the parallel wavelength ($l/\lambda_{\|}$) affects coupling efficiency for whistler waves enabling experimental tests of previously unvalidated theories [2]. And knowing the electric dipole's complex impedance dependance of frequency and antenna length will help us understand DSX's results, given the measured radiation resistance on DSX differs by orders of magnitude from existing theories.[3]

References
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