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Whistler Mode Wave Injection and Radio Sounding Experiments from the Demonstration and Science Experiments (DSX) Satellite

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Spaceborne whistler mode (WM) wave injection experiments offer unique ways to investigate some of the outstanding problems in magnetospheric physics: (1) physics of nonlinear wave-particle interactions, (2) ducted and nonducted WM propagation, (3) factors governing penetration of WM signals to the ground, and (4) properties of a very low frequency (VLF) antenna operating in the nonlinear regime at high voltages in space. Whistler mode radio sounding from space provides a novel method to measure field-aligned electron and ion densities and density structures [1]. In this paper, we discuss the feasibility of various WM wave injection and radio sounding experiments (3-50 kHz) from the Demonstration and Science Experiments (DSX) satellite (6000-to-12,000 km, 42° inclination) [2].

Using the Stanford 2-D ray tracing program, we present simulations of DSX signals propagating in whistler mode to investigate the various scenarios and likelihood of: (1) DSX signals returning to DSX as echoes; (2) DSX signal reception on the ground; and (3) DSX signal reception on other satellites. We performed ray tracings when DSX was located (1) inside the plasmasphere at $L = 2.8$, $\lambda_m = 0°$, and (2) outside the plasmasphere at $L = 6$, $\lambda_m = 50°$.

Ray tracing simulations predict four types of echoes when DSX transmits in the whistler mode frequency range: (1) magnetospherically reflected (MR), (2) normally incident specularly reflected (NI-SR), (3) obliquely incident specularly reflected (OI-SR), and (4) plasmapause guided (PP). Based on our experience with WM radio sounding from IMAGE, we expect to detect these echoes on DSX. Characteristic dispersion and cutoff frequencies of these four types of echoes permit the determination of electron density, ion composition, and location and scale sizes of density irregularities in the magnetosphere [1].

Ray tracing results also show that DSX signal can reach the ground by three distinct mechanisms: (a) nonducted propagation at small wave normal angles, (b) nonducted propagation at large wave normal angles, followed by a mode conversion process involving field-aligned irregularities (FAI), and (c) ducted propagation. Estimates of the magnetic field strength of the DSX signal reaching the ground indicate that the most likely mechanisms by which detectable DSX signals ($\sim$10 fT/Hz$^{1/2}$) may reach the ground are: (1) nighttime nonducted propagation followed by a mode conversion by FAI when DSX is inside the plasmasphere and f~15 kHz, where f is the signal frequency, and (2) nighttime ducted propagation when DSX is outside the plasmasphere and f~3 kHz. Our results show that a receiver located within ~300 km of the ionospheric exit location of the DSX signal should detect the DSX signal.

Raytracing calculations show that DSX signals can reach other low altitude satellites, such as CASSIOPE (325-to-1500-km), and high altitude satellites, such as ARASE (~ 460-to-32,000km). With the expected longitudinal spread of <30° for rays injected from a satellite [3], the conjunction experiments with CASSIOPE/ARASE should be planned when their longitudes are within ~30° of DSX longitude. Such conjunction experiments will permit studies of wave-particle interactions, WM wave propagation, and electric antennas at VLF frequencies.

We discuss the implications of our results for addressing the fundamental problems mentioned above.

References

[1] V. S. Sonwalkar, A. Reddy, and D. L. Carpenter, "Magnetospherically reflected, specularly reflected, and backscattered whistler mode radio-sounder echoes observed on the IMAGE satellite: 2. Sounding of electron density, ion effective mass (m_{eff}), ion composition (H^+, He^+, O^+), and density irregularities along the geomagnetic field line," *Journal of Geophysical Research*, **116**, 2011, pp. A1121.

[2] J. McCollough, "Active experiments with the DSX mission," Sep. 2017. [Online]. Available: https://cnls.lanl.gov/External/aefy17/19_McCollough.pdf [Accessed: Jan. 28, 2021].

[3] V. S. Sonwalkar et al ., "DE 1 VLF observations during Activny wave injection experiments," *Journal of Geophysical Research*, **99**, 1994, pp. 6173.