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VLF Transmitter for DSX mission in the Radiation Belts

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The US Air Force Research Laboratory (AFRL) Demonstration and Science Experiments (DSX) mission (e.g., [1] and references therein) launched a very low frequency (VLF) transmitter to an elliptical Medium Earth Orbit (MEO) with a perigee of 6000 km, an apogee of 12000 km, and 43º inclination to conduct wave-particle interaction experiments (WPIx) in the Van Allen radiation belt. The transmitter is a follow-on project to a successful Radio Plasma Image (RPI) instrument [2] on NASA IMAGE spacecraft [3] developed at University of Massachusetts Lowell in the late 1990s for VLF-to-MF total-reflection radio sounding in the plasma environments of the Earth. Feasible spaceborne implementations of the total-reflection VLF sounder have to operate with electrically short antennas (e.g., in order to transmit on a half-wavelength dipole in free space at 10 kHz, a 15 km antenna is required). The RPI instrument was the first to attempt such transmission using its 500 x 500 m long-wire crossed dipole. There are two challenges to VLF transmission on an electrically short dipole. First, for $f < 300$ kHz, the antenna impedance is mainly capacitive with a large reactance of $X_a = 1/\omega C_a$ where the capacitance C_a of the 500-m dipole is 533 pF. A very high voltage is therefore required to drive a sufficiently high current I_a into the antenna. Secondly, the radiation efficiency is very poor at low frequencies. Correspondingly, RPI transmission power could not reach levels much above 1 mW in the VLF band [2]. The new spaceborne transmitter for DSX takes the RPI heritage to the next fidelity level by carefully evaluating the key design factors: antenna design, scalability of the high voltage operations, waveform generation, and adaptive tuning for optimal transmission within the varying plasma environments. Early results from VLF transmissions on DSX are discussed.

References

[1] DSX (Demonstration and Science Experiments) in MEO, *Earth Observing (EO) Resource Directory.* Retrieved on February 3, 2020 from https://directory.eoportal.org/web/eoportal/satellite-missions/content/-/article/dsx
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[3] Burch, J. (2000), IMAGE mission overview, *Space Science Reviews,* IMAGE special issue, 91, 1–14. doi:10.1023/A:1005245323115.