Impedance Characteristics of an Active Transmitting System in Space Plasma

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The RPI/IMAGE satellite-borne sounding system was used to investigate the characteristics of a high power transmitter and dipole antenna in space plasma. Routine RPI active soundings were done in the so-called plasmagram mode where the frequency was typically stepped over a range from 100kHz to several megahertz. During these normal soundings the transmitting system was "tuned" using various inductor and capacitor combinations that were automatically switched in and out at each frequency step. As part of the routine operation, current measurements were made in the power supply and voltage measurements were made at the input terminals of the thin wire uneven dipole antenna. Earlier in the IMAGE mission, one of the dipole elements was broken and shortened by approximately one half, i.e. the original unbroken element was 250m long while the damaged element was approximately 125m. In the summer of 2005 it was recognized that using the RPI/IMAGE system it would be possible to determine the input impedance of an active transmitting antenna in plasma by stepping the frequency to find the best tuning in terms of the highest voltage on the input to the antenna. On September 21, 2005, the so-called "V71" experiment was carried out for two orbits of the IMAGE satellite. The data was collected every four minutes for portions of two passes beginning outside the plasmasphere and then through the plasmasphere, over the polar cap region and again through the plasmasphere. The frequency range selected for V71 experiment was 18 to 80 kHz in 300 Hz steps with a dwell time on each frequency of $\approx$1s. From this experiment it was possible to determine the input impedance characteristics of the dipole antenna located within plasma. The plasma around each antenna element formed a cylindrical ion sheath, which varied in radius depending inversely on the square root of the ambient electron density. Within the plasmasphere, these sheaths are part of the antenna system and represent the capacitive component of the tuned circuit. The real part of the input impedance represents losses associated with the motion of electrons as the sheaths grow and decay during the RF cycle. The radiation resistance appears to represent a small fraction of the total (10 to 15 percent) antenna resistance. The remaining antenna system losses occurred in a relatively collisionless plasma inside the plasmasphere. It is shown that there is a good correlation between the variation of the antenna loss resistance and the local electron cyclotron frequency. In order to extend this analysis to other proposed high power transmitting systems within the plasmasphere, future efforts will include the development of a general model of a high power transmitting system in plasma based on these results.