ADAPTIVE ANTENNA TUNING FOR TRANSMISSION IN SPACE PLASMA

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It is of paramount importance that an antenna in space plasma is tuned during its whole cycle when high power and efficiency is required. In plasma and at very low frequencies (3 to 100 kHz), an antenna changes its capacity continuously, twice within a cycle, as a function of its charges. The antenna also experiences a negative space charge.

To maintain this space charge during the transmission, the electron current on the positive side of the antenna must equal the ion current on the negative side during one half cycle. In reference to the surrounding plasma, the maximum positive voltage is less than 6 % of its amplitude for proton plasma and only 2 % for oxygen ion rich plasma. But the maximum negative voltage is almost twice the amplitude.

Two equal transmitters, feeding the antenna, have been chosen for redundancy and for minimum field strength near the spacecraft. Minimizing the capacity change to less than a factor of two requires isolation of the midpoint between the two transmitters from the body of the spacecraft and connecting the midpoint via a large resistor to the spacecraft. This allows the spacecraft to float to the average voltage of the antenna without drawing much current. Anyway, the current charging the antenna is negligibly small.

To get any reasonable power out of the antenna, it has to be tuned by an inductor. Tuning has to be precise because the ratio of the capacitive impedance to the losses of the inductor and the antenna is enormous at those frequencies. But compensating the changing capacity of the antenna by changing the inductor impedance during a cycle requires more energy than available for transmission. Therefore a scheme of four inductors has been developed, tuned simultaneously to the wanted frequency and its three next odd harmonics. Basic tuning is carried out by parallel capacitors or changing the frequency in small steps. While the maximum current is applied to the inductor for the basic frequency, amplitude and phase of the harmonic currents can be controlled. In regular intervals, the voltage and current at 56 locations within a cycle are measured. These 56 locations are the zero crossings of the sine and cosine components of the harmonics. Necessary corrections are computed automatically to keep the system tuned when the plasma conditions change. Another advantage of this method is the possibility of correcting the non-linearity of the main inductor under large power conditions.

The described method not only optimized the radiated power of the antenna, but also measures the properties of the antenna in space, including the formation and size of the plasma sheaths as a function of the applied charges, the losses caused by the currents from the plasma into the antenna, and the radiation resistance. Even localized changes in plasma frequency can be monitored.