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Wideband impedance probe for measurements of lower hybrid resonance (LHR) in the ionosphere - Lessons Learned in SS-520-3

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Wideband impedance probe (WNEI) was installed on SS-520-3 (launched in 2021) for determination of the ionospheric ion composition based on lower hybrid resonance (LHR) frequency. Design of the wide band impedance probe was based on that of the impedance probe for electron number density measurement (NEI) for the previous sounding rockets. The operation frequency range of WNEI was extended below up to 1 kHz in order to measure the probe capacitance decrease at LHR frequency around several kHz in the ionosphere. Determination of ion components using impedance probe operated around LHR frequency was already proposed by Miller and Schulte (1969). However, there was no report of actual applications of the wideband impedance probe to the ionospheric observations. The purpose of this study is to summarize the issues in application of WNEI to the ionospheric observations found in SS-520-3.

The WNEI was operated successfully during the flight of SS-520-3. The probe capacitance in a frequency range from 1 to 11 kHz could be measured in an altitude range from 160 to 740 km. However, in the analysis, the following issues were needed to be considered:

(i) Since the capacitance of the probe and surrounding ion sheath with a length of 1 m is about 30 pF, their impedance exceed 1 Meg ohm below 5.3 kHz. The signal level applied to WNEI capacitor bridge is several V. The currents in the loads of the bridge are therefore estimated to be less than several micro A below 5.3 kHz, which has little margin to the level of the surrounding noises. So, the datasets below 5.3 kHz are excluded from the analysis in this study.

(ii) Even above 5.3 kHz, the interference of the noises with odd harmonics of 156.5 Hz probably from the instruments installed on the rocket were also found in the WNEI data. The noises were also found in the prelaunch tests on the ground while their level was much smaller. They are more apparent when the probe was in the rocket wake. It is because the signal level proportional to the probe (with sheath) capacitance decrease in the rocket wake while the interfered noise level is constant.

(iii) In addition to the interfered noises, we could find another components of probe capacitance decrease with large deviation. They can be identified with criteria as probe capacitor decrease with a deviation of 2.5 sigma, where the sigma is standard deviation of probe capacitance in each profile with respect to the running average. They are around 7.6 kHz at an altitude around 730 km (400-500 s from the launch), and around 8.2 kHz at an altitude around 710 km (550-600 s from the launch), respectively, which are similar LHR frequency estimated from NEI data (electron number density) and IRI-2016 model with assuming the abundance of heavy ion as O+ is 95 and 90%, respectively. The reason why the large probe capacitance decrease can be found only in the wake is because the collision frequency of electrons with ions decrease in the rocket wake, which results in the probe capacitance decrease at LHR frequency with high Q value.

The future plans for solving the issues of WNEI found in SS-520-3 will be discussed in the presentation.