Lessons Learned from Previous Space-Borne Sounders as a Guide to Future Sounder Development

Robert F. Benson[1], **Mark L. Adrian**[2], **Manohar D. Deshpande**[3], **William M. Farrell**[4], **Shing F. Fung**[5], **Vladimir A. Osherovich**[6], **Robert F. Pfaff**[7], **Douglas E. Rowland**[8]

[1]Code 673, NASA/Goddard Space Flight Center, Greenbelt, Maryland 20771 USA robert.f.benson@nasa.gov

[2]mark.l.adrian@nasa.gov[1]

[3]Code 555, NASA/GSFC, Greenbelt, Maryland 20771 USA manohar.d.deshpande@nasa.gov

[4]Code 695, NASA/GSFC, Greenbelt, Maryland 20771 USA william.m.farell@nasa.gov

[5]shing.f.fung@nasa.gov[1]

[6]Code 673, CUA/GSFC, Greenbelt, Maryland 20771 USA vladimir.a.osherovich@nasa.gov

[7]Code 674, NASA/GSFC, Greenbelt, Maryland 20771 USA robert.f.pfaff@nasa.gov

[8]douglas.e.rowland@nasa.gov[7]

Space-borne radio sounding is considered to be the gold standard for electron-density (N_e) measurements compared to other techniques even under low-density conditions, such as $N_e < 1$ cm^{-3}, when other techniques are known to experience difficulties. These reliable measurements are not restricted to *in-situ* N_e determinations since a space-borne sounder can provide vertical N_e profiles (N_e(h)) from the spacecraft altitude to the altitude of maximum N_e. Near-conjunction studies involving the International Satellites for Ionospheric Studies (ISIS) satellites in the topside ionosphere and Dynamics Explorer 2 (DE 2) near the altitude of the F-region peak density have verified that, even at the greatest distance from the sounder, the ISIS-derived N_e(h) profiles agree with the DE-2 Langmuir-probe measurements to within about 30% over a density range of more than two decades. Space-borne sounders can also provide N_e profiles along the magnetic-field **B**, by inverting echoes that are ducted along field-aligned irregularities (FAI), and can provide information about the terrain beneath the satellite by examining surface reflections in the frequency range above the ionospheric penetration frequency. Many nations have launched rocket and satellite radio sounders in geospace over more than 4 decades and there have been sounders on space-probes and in orbit around other planets. Here we will summarize some of the lessons learned from these accomplishments by analyzing data from radio sounders on the Alouette and ISIS satellites and the OEDIPUS and other rockets in the terrestrial ionosphere, the IMAGE satellite in the terrestrial magnetosphere, the Ulysses space probe in Jupiter's Io plasma torus and the MARSIS satellite in orbit around Mars. The emphasis will be on information deduced concerning (1) fundamental plasma processes and gradients in N_e and **B** in the vicinity of the sounders from sounder-stimulated plasma resonances and short-range echoes involving ion as well as electron motions, (2) the importance of the antenna orientation relative to **B** for the detection of different plasma resonances, (3) sounder-stimulated plasma phenomena, including FAI, when special plasma conditions are satisfied, (4) the minimum power required for long-range echoes, as indicated by echoes from frequency components of the transmitted pulse and by multiple ducted echoes, and (5) the terrain beneath the satellite from surface reflections. Knowledge of these results should enable the optimum design of a future sounder to satisfy specific science requirements with minimal spacecraft resources.