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Active experiments beyond the Earth: Effects of sounding radar operations in the ionospheres of Venus, Mars, and the Jovian system

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Operation of powerful satellite- and rocket-born sounding radars is often accompanied by a heating/acceleration of the local electrons and ions. On earlier missions, intense fluxes of sounder accelerated particles were detected in Earth's ionosphere when the frequency of the radar transmitter was close to one of the fundamental plasma resonances: harmonic of the electron-cyclotron frequency, plasma or upper-hybrid frequencies. Recently it was found that running a sounder in the ionosphere of the non-magnetized Mars results in the similar effects. Ion and electron sensors of the ASPERA-3 experiment (Analyzer of Space Plasma and Energetic neutral Atoms) onboard the Mars Express spacecraft discovered acceleration of the local ionospheric ions and electrons from thermal threshold energies to 100's of eV during the active sounding phase of the onboard sounder. ESA and NASA missions in development or under study to Jupiter (JUICE- JUpiter ICy moon Explorer in 2022, Europa Clipper in 2023) and to Venus (EnVision in 2032) will also carry powerful sounding radars. In this report we review mechanisms that can cause acceleration of the plasma particles during operations of the proposed sounding radars in the Jovian system and Venusian ionosphere. Using the results of previous studies and characteristics of the proposed sounding radars onboard JUICE, Europa Clipper, and EnVision we define the optimal conditions for observations of sounder accelerated particles, depending on the local conditions, such as plasma density, composition, and intensity of the magnetic field. The EnVision radar operation is expected to results in the most pronounced acceleration of ions and electrons, an effect can be used to improve the local plasma diagnostics.