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Advanced Radio Science Instrumentation: Architectures, Applications & Recent Use

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Since the beginning of planetary probe exploration, radio communications have provided critical downlink from the exploring spacecraft to Earth-based receiving radio telescope antennas. In addition to providing valuable data downlink from onboard instruments, the radio link is also used as a science instrument itself referred to as Radio Science. Radio science investigations probe the atmosphere and ionosphere of celestial bodies with occultations, surface properties with bistatic scattering, and interior mass distribution by measurement of gravitational field parameters. These scientific objectives can be accomplished with the use of advanced onboard instrumentation, including onboard open-loop recorders, spacecraft-to-spacecraft radio links, multiple frequency transponders, small satellites, and cubesats. Recent planetary missions have utilized advanced radio science instrumentation in novel architectures to advance the precision, accuracy, and scope of possible investigations. The New Horizons Radio Science Experiment utilized a novel uplink-only radio science instrument with the spacecraft recording the received signal in an onboard open-loop recorder (REX) to determine the atmospheric and physical properties of Pluto and Charon. Most recently on January 1, 2019, the REX instrument was used for surface characterization of MU69 “Ultima Thume” Kuiper Belt Object using the same uplink-only architecture. In 2018, the first planetary science was conducted with a cubesat as the twin MarCO spacecraft flew by Mars. During their flyby of Mars, the pair of cubesats performed real-time relay of the InSight lander’s radio link and also performed a radio occultation of Mars’ atmosphere to determine temperature and pressure of the Martian atmosphere. The ongoing Juno Gravity Science Experiment is the first mission to utilize dual and simultaneous X- and Ka-band up and down radio links between the spacecraft and antennas at Earth for geodesy, providing an unprecedented view of Jupiter’s internal structure. This work will discuss architectures for implementation of radio science instruments, recent use of advanced instrumentation, and highlight the scientific return of these investigations.