Development of the bistatic radar system for subsurface radar sounding of the satellites and asteroids

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Recent explorations clarified that the surfaces of the terrestrial planets, satellites and small bodies in the solar system are covered by regolith, and that the composition of the internal material is not always the same with the composition of the regolith on the surface. For example, the mass density of 21 Lutetia is as high as that of metallic meteorites, while its surface is covered by regolith with stony composition. The surfaces of Saturn's moons Helene and Atlas are contaminated by the ring particles. Disagreement between the chemical map measured by gamma-ray spectrometer and geological features on the Martian surface suggests that the Mars is covered by thin regolith layer with homogeneous composition. It makes difficult to estimate the amount of the carbonate rocks under the ground, and discuss the presence of the ancient humid subtropical climate on the Mars. Even if we can obtain numerous data on the surface of the planets, satellites, and small bodies in our future solar system exploration, we can not avoid the difficulty that the information on the surface doesn't always show the information bedrocks. In order to solve the problem, we consider that it is essential to acquire the technique of subsurface radar sounding of the planets, satellites, and small bodies with enough accuracy and resolution.
In 2000s, global subsurface radar sounding of the Mars and the Moon was performed by radar sounders onboard the Mars Express, MRO, and SELENE [Picardi et al, 2005; Seu et al., 2007; Ono et al., 2009]. Their resolution was several to several ten meters. In Chang'E-3 mission in 2013-2014, ground penetrating radar onboard the rover was operated in a local area on the Moon, and observed subsurface structures at a resolution of 0.33 m [Xiao et al., 2015]. In Rosetta mission, the bistatisc radar system was installed on the orbiter and lander of the 67P/Churyumov-Gerasimenko. The bistatisc radar observations was performed in 2014, and reported permittivity of the ice including some voids below the surface [Kofman et al., 2015]. In this study, we focus on the development of the spaceborne bistatic radar sounder system for small satellites and asteroids because Japan has strength in the exploration of the asteroids, and we can expect penetration of radar pulse through such small bodies, which is important in the bistatic radar observation.
In spaceborne bistatic radar system, it will be difficult to provide the same clock to the two radar units (e.g. transmitter and receivers) at different locations in space. So, we install transmitter and receiver into one radar unit (Unit-A, hereafter), and transponder into another unit (Unit-B, hereafter). In the observation, radar pulse is transmitted from Unit-A, propagates through the asteroid, and reaches Unit B. Transponder in Unit-B receives radar pulse, and transmits another radar pulse immediately. The radar pulse from Unit-B propagate back through the asteroid, reaches receiver in Unit-A. The same clock can be provided to the transmitter and receiver in Unit-A. From the delay time between transmitting radar pulse and receiving radar pulse, we can determine the round trip time of the radar pulse. In bistatic radar observation, we have to discriminate the radar pulses with different history of propagation path and relay at transponder in Unit-B. So we are planning to use coded signal for radar pulse and add information of transmission and relay history on radar pulses.

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