2nd URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018

CubeSat based radio tomography for a rubble pile asteroid: DISCUS mission concept

Mika Takala[(1)], Patrick Bambach[(2)], Jakob Deller[(2)], Esa Vilenius[(2)], Manfred Wittig[(4)], Harald Lentz[(3)], Hans Martin Braun[(3)] and Sampsa Pursiainen[(1)]
(1) Laboratory of Mathematics, Tampere University of Technology, Tampere, Finland
(2) Max Planck Institute for Solar System Research, Goettingen, Germany
(3) RST Radar Systemtechnik Gmbh, Salem, Germany
(4) MEW-Aerospace UG, Hameln, Germany

Extended Abstract

This presentation concentrates on the possibility to perform radio tomography measurements using CubeSat spacecraft carrying a bistatic radar. We present both simulated tomography results and the conceptual DISCUS (Deep Interior Scanning CubeSat) spacecraft design.

Rubble-pile asteroids are celestial bodies bound together by a weak gravitational field and are, therefore, likely to contain macroporosity, e.g., internal voids. Based on the observations of rotation periods, asteroids with diameter around 200–300 m are not monolithic, but in the vast majority, rubble pile asteroids. Moreover, the estimated density for the rubble piles suggests that the macroporosity exists but the actual proof is still missing. Therefore, we find that a rubble pile asteroid is an ideal reference target for this type of mission.

DISCUS is a tandem CubeSat concept to investigate the macroporosity structure and 3-dimensional dielectric permittivity distribution of a 260–600 m diameter Near Earth Asteroid (NEA) from a few kilometers distance. DISCUS is planned to be flown either as an independent mission or accompanying a larger one. Using two CubeSats for a bistatic Radar measurement was first proposed for the AIM mission [1]. In order to guarantee a sufficient signal penetration, the goal is to use a low, e.g., 20 MHz signal frequency, which is known to be ideal regarding both void detection [2] and also the background noise in the solar system [3, 4]. The main goal will be to achieve a global signal penetration as well as to analyze the scattering strengths for different depths and positions. The planned radar is based on stepped-frequency technology [5] which is used, for example, in helicopter-borne ground penetrating radar imaging of glaciers. It provides high performance, but requires only little DC power and operates with low data rate and volume. Narrow frequency bands are to be transmitted and received separately. A large number of frequency lines can be measured at a single point, i.e., a high signal-to-noise ratio can be obtained for the covered 2 MHz bandwidth.

In the numerical experiments, we have investigated a three-dimensional NEA model containing deep interior anomalies and a surface dust layer. The radar parameters planned for DISCUS were used. The inversion accuracy and reliably were explored for several different noise levels and also for a situation where the trajectory possibilities for the spacecraft are limited. A full-wave tomography approach was applied in order to maximize the imaging quality and to allow the sparsity of the measurements which is vital due to the possible limitations which, in a space mission, follow from various reasons.

References

[1] A. Herique and V. Ciearletti, "A Direct observation of the asteroids structure from deep interior to regolith: Two radars on the AIM mission," *47th Lunar and Planetary Science Conference*, 2016, p. 2096.

[2] R. P. Binzel and W. Kofman, "Internal structure of Near-Earth objects," *Comptes Rendus Physique*, vol. 6, no. 3, pp. 321-326, 2005.

[3] B. F. Burke and F. Graham-Smith, "An introduction to radio astronomy," *Cambridge University Press*, 2009.

[4] R. G. Stone, K. W. Weiler, M. L. Goldstein and J.-L. Bougeret, "Radio astronomy at long wavelengths," *Washington DC American Geophysical Union Geophysical Monograph Series*, vol 119, 2000.

[5] H. Lentz and H. Braun, "Ginger II: An upgrade of the technology demonstrator of the Guidance and INto the Ground Exploration Radar GINGER," *Advanced Space Technologies for Robotis And Automation (ASTRA 2000)*, ESTEC, Noordwijk, Holland, paper 3.5, 2000.