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SMALL SATELLITE BISTATIC SAR 3D CHARTING OF AN ASTEROID

Abstract

The current understanding of the internal structure of asteroids is still limited and depends mostly on information inferred from remote-sensing observations of their surfaces, derived shapes and spins and previous impacts. This has motivated the interest in deep-space exploration missions to perform the first in-situ measurements of their subsurface. The most mature method for this type of measurements is Synthetic Aperture Radar (SAR). This paper presents an S-band SAR dual-orbiter configuration that can achieve a tridimensional metric resolution allowing the identification of layers within an asteroid and a link of surface measurements to its internal structure. The asteroid under study is Didymos, a binary asteroid target of multiple missions such as NASA's Double Asteroid Redirection Test (DART) and ESA's Hera. The chosen radar geometry takes advantage of the orbital motion of the asteroid moon ("Didymoon") and an artificial movement orthogonal to its orbital plane provided by the bistatic configuration to create a tridimensional chart of Didymoon. The instrument suit required consists of minimal and existing equipment. A bistatic configuration enables a higher pulse repetition frequency, thus improving the signal-to-noise ratio. S-band provides a good balance between antenna size, resolution and penetration on the low-density material that constitutes the asteroid. Moreover, it allows to share the antennas with other systems such as communications. Additionally, the experiment can be integrated with a time division communication protocol, that allows the coordination between transmitter and receiver spacecrafts and other simultaneous operations. With a transmitted power of 5 W, the proposed system can detect, with a one-meter tridimensional resolution, a target with distributed reflectivity of less than -60 dB/dB on the surface of the asteroid moon and of less than -20 dB/dB at a depth of nearly 5 meters. At each of Didymoon's relative orbit of 11.3 hours, the acquisition mode is activated for approximately 20 minutes until the completion of the 8-week mission. The duty-cycle between pulses within each of these acquisitions is about 5%. The SAR processing can improve the orbit accuracy during an acquisition phase by using a combined wide-band signal of around 200 MHz achieved by accumulating smaller bandwidth pulses to determine the relative positions of the satellites. The paper includes a satisfactory validation of the approach performed in an anechoic chamber, using the microwave analogy. In this way, a scaled target with similar electrical characteristics as the predicted for the asteroid and an appropriately scaled working wavelength were chosen.