Potential of a Multimodal Orbital Radar Mission for the Exploration of Enceladus

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An Enceladus mission launched within a realistic time frame (e.g., launch between 2025 and 2040 and a transfer time of about ten years) would likely arrive as the sun is departing or gone from the most interesting South Polar Region marked by its active jets erupting through the ice crust. This almost drives the need for a radar instrument enabling the imaging, mapping and characterization of the moon independent of sunlight illumination. The known ice penetration capability of radar waves in the tens of MHz up to few GHz range allows for the exploration of subsurface features, whereas the surface may be imaged with high level of detail in higher frequencies up to several tens of GHz. In the frame of the Enceladus Explorer Initiative (EnEx) of the German Aerospace Center (DLR), we are currently investigating the potential of a multimodal orbital radar instrument to be used as a companion to a lander mission and to contribute in the understanding of the structure, composition and temporal variation of the Enceladean ice crust and the involved geophysical processes.

The considered orbit geometries, strongly constrained by the presence of Saturn, allow for global coverage and offer half-daily revisit of the South Polar Region. We suggest a multi frequency system working concurrently in high frequency (e.g., Ka-band) and lower frequency (e.g., P-band) for surface and subsurface exploration, respectively, both capable of operating in a variety of modes: i) high resolution imaging used as a synthetic aperture radar (SAR), ii) SAR interferometer for topography, permittivity and surface and volume deformation estimates, iii) nadir looking configuration operating as an altimeter for elevation estimates and as a sounder for subsurface exploration with great penetration capability, iv) radiometer for surface temperature estimates and inversion of temperature profiles, and v) bistatic measurements between the radar instrument and an ice penetrating probe deployed by the lander with similarities to the CONSERT instrument of ESA's Rosetta mission.

In this presentation, we evaluate the potential of the different modes concerning their scientific output and their usefulness for supporting the success of a lander mission. In particular the performance of SAR imaging and interferometry (single- and repeat-pass) modes are analysed, which are expected to provide key information for landing site selection such as structure, composition and topography of the surface and subsurface with metric resolution. For validation,
we present results of a SAR campaign conducted using DLR’s airborne sensor F-SAR over an alpine glacier, with simultaneous X- and L-band acquisitions. The campaign incorporates repeat- and single-pass acquisitions, as well as circular flights, which provide interferometric and tomographic measurements with observation geometries similar to those of an Enceladus mission. Furthermore, we provide an analysis towards a bistatic sounding experiment. Utilizing the transmission line between the radar instrument and a transponder integrated in an ice penetrating probe allows for the inversion of the spatial distribution of the dielectric ice properties and associated geophysical parameters (e.g., density, grain size, temperature, and salinity).