
Introduction: Imaging radars with wavelengths in the range of 10 cm to 1 m can deeply penetrate the surface of an icy body, revealing details of the geomorphology, local structure, and electrical properties of the upper layers. Radar studies of icy surfaces on Earth have used the polarization state of backscatter echoes at multiple frequencies to characterize the surface and subsurface properties of glaciers, showing relatively smooth surfaces on the scale of radar wavelengths, and subsurface scattering from volume scatterers consistent with ice pipes and lenses [1, 2]. These volume scattering effects are evident in enhanced polarization ratios over a limited range of backscatter incidence angles. The Galilean satellites exhibit similarly enhanced polarization ratios and volumetric scattering effects [3], but the observations are limited in angular resolution, leading to ambiguity in interpreting the scattering mechanisms and their structural implications.

Subsurface Imaging: Polarimetric radar observations of the Galilean satellites at decimeter-scale wavelengths are well-suited to addressing some of the poorly understood characteristics of the icy surfaces. An imaging radar has vastly improved resolution, allowing detailed association of scattering mechanisms with geomorphological structures. Where the surfaces are smooth and volumetric effects are small, a long wavelength imaging radar probes deep into the ice, allowing characterization of the spatial variability of ice layers. Where the volumetric effects dominate, presumably due to impact events, the radar can measure the depth and extent of the gardened layer. Fully polarimetric observations enable polarization synthesis needed to explore the unique scattering mechanism of these bodies.

Bistatic Imaging: With powerful transmitters at the DSN capable of illuminating the Galilean satellites, or using the high power transmit capabilities of an orbiter in conjunction with a DSN receiver, probing the coherence properties of the surfaces can be enhanced. All observations to date, as well as conventional imaging radars, are monostatic, giving an incomplete picture of the volume scattering mechanisms. Bistatic observations of the complete scattering function would give valuable new insight into these mechanisms.

Repeat-pass interferometry and volumetric response of the upper layers: When a radar satellite is maneuvered to follow exact repeat orbits, it is possible to observe a surface feature from exactly the same vantage point. Under this viewing condition, phase differences between radar images acquired from one observation time to the next can record any motion of the surface. The field of glaciology on Earth has been transformed by such “repeat track interferometry” observations, as images of ice velocity measured over several days and accelerations measured over months in Greenland, Antarctica and temperate glacial zones have shown ice sheets and glaciers to be far more variable than previously thought [4]. Dynamic changes of the shape of the Galilean satellites in response to tidal forces can be tracked at the mm to cm level of precision if the repeated orbital constraints can be met and the radar has sufficient transmit power.

The quality of the interferometric observations is influenced by several factors: intrinsic radar backscatter levels, resurfacing effects, repeat orbit track separation (baseline) and volumetric scattering effects. Radar brightness is expected to be sufficiently high for good imaging [3] and resurfacing should be very small over the duration of the missions. For non-zero baseline, the interferometric signature is a combination of the displacement of the surface, and the parallax-induced topographic signature. To separate the two, an independent interferometric measurement must be made, or an independent topographic map must be available. In addition to the phase difference measurement, a measure of the correlation between images can be derived from the data.

In addition to measuring resurfacing and brightness variations, the correlation is a sensitive measure of the extent of scattering within the penetrated surface volume [5]. The effects of volumetric decorrelation increase with baseline separation, as the directivity of the mutual coherence of the backscattered field is proportional to the scattering volume. Therefore the volumetric correlation could be one of the most effective means for characterizing the depth of the impact-gardened surface layer.

References: