Observations of the Surface of Comet 67P/C-G by RSI Operating in Bistatic Radar Configuration

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Towards the end of year 2014, the Radio Science Investigation (RSI) on Rosetta conducted a bistatic radar (BSR) probing campaign of the surface of comet 67P/Churyumov-Gerasimenko (67P/C-G). The radio transmitter on the spacecraft beamed a right circularly polarized (RCP) carrier wave towards a predicted specular reflection point on the comet's surface. The two available communication wavelengths – 3.6. cm (X-band) and 13 cm (S-Band) were simultaneously broadcasted. A station of the NASA Deep Space Network (DSN) coherently recorded both RCP and left circularly polarized (LCP) open loop samples using the 70-m antenna infrastructure. By simultaneously tracking opposite circular polarizations, the need for an absolute calibration of the individual receiver channels could be prevented. In turn, a specifically designed relative calibration procedure was used. The recordings contained direct signal contributions from the main and side-lobes of Rosetta's high-gain antenna (HGA), as well as scattered echoes from the comet surface.

For a known angle of incidence and measured RCP/LCP power ratio of the returned echo signal, the dielectric constant of a gently undulating reflecting surface can be estimated following Fresnel's reflection theory. This procedure is currently being used to study the surface of Mars using the Radio Science experiment MaRS aboard Mars Express. The underlying hypothesis presumes that the illuminated surface is sufficiently smooth to reflect most of the scattered signal power in the specular direction. However, for the rough surface areas observed by RSI on comet 67P/C-G this assumption is not granted and detailed modelling of the comet's radar cross section (RCS) is necessary for interpretation.

A total of six BSR measurement tracks were conducted by Rosetta. The HGA swept equatorial regions on the comet in five of the experiments. On November 29, the HGA footprint was close to the comet's north rotation pole, while Rosetta orbited at a distance of 30 km. The strongest (few zeptowatts) RCP and LCP signal returns where detected on this occasion. The slowly varying relative geometry between Rosetta and the reflection point on the surface accounted for spectrally distinct (but close within 1 Hz) direct and echo signals. The stability of the transmitted carrier signal was guaranteed by an ultra-stable oscillator built into RSI. The roughness scale of the observed surface could be quantified using available comet shape models. The predicted spectral spread of the echo signal amounts to values comparable to the spectral separation, causing the overlap of the two signals. Hence, spectral estimation needed to be applied cautiously to successfully remove direct signal components and derive reliable power estimates for the cometary BSR echo signal.