Sub-Surface Radar for the EJSM mission: discussion on environmental noise limiting performance

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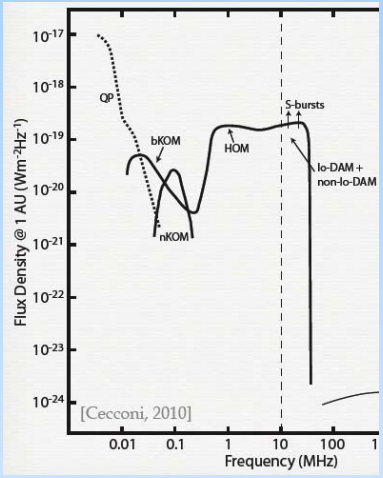
Abstract

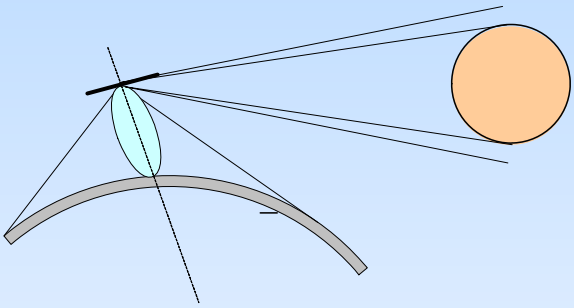
The Europa Jupiter System Mission (EJSM) is one of the major European Space Agency (ESA) missions in the Solar System currently under study. It is aimed at exploring Jupiter and its icy moon Ganymede. The Sub-Surface Radar (SSR) instrument is a radar sounder system at low frequency (HF/VHF band) designed to penetrate the surface of Ganymede icy moon of Jupiter for performing a subsurface analysis with a relatively high range resolution. The paper addresses the main sources of environmental noises that can limit the overall performance of the radar: the presence of a relevant Jupiter radio emission and the clutter caused by characteristics of planet's surface.
Recently scientific objectives of the mission, now called Jupiter Icy Moon Explorer (JUICE), has changed to include also exploration of Europa, by means of a pair of flybys

Two main sources of environmental noises have been identified so far as limiting in radar performance:

- **Jupiter's radio emission**
- **Moon's surface clutter**

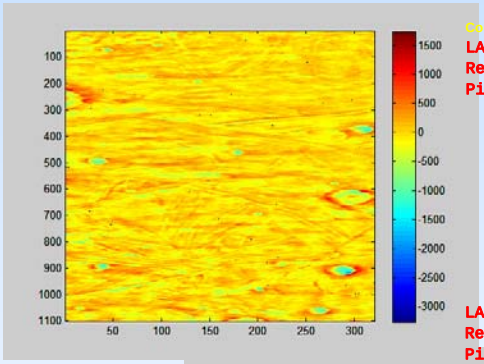
As far as the first noise source, it is well known that Jupiter is a so bright radio object that, as seen from Earth, it is exceeded only by the Sun. The most intense radio emission occurs in the frequency range between few megahertz and about 40 MHz [3], and it is expected to be due to cyclotron radiation originating in and above the ionosphere. These radio emissions dominate the galactic background, which is usually the major source of noise for planetary radar measurements. Decades of ground based and space based observations provided a good knowledge of the characteristics of these emissions. Ground based observations are limited by the terrestrial ionospheric cutoff which reflects out radio waves with frequencies lower than 10 MHz. Space based observations are usually limited at high frequencies because of the limited resources available on a spacecraft. In particular, by using data of the Planetary Radio Astronomy (PRA) experiment on both Voyager spacecrafts and by the Cassini Radio and Plasma Wave Science instrument (RPWS), the expected spectral flux density of Juppiter radiation at Ganymede.





The effects of such radiation noise on SSR instrument can be evaluated by taking into account either the direct part coming from Jupiter and the portion backscattered by Ganymede's surface [1].

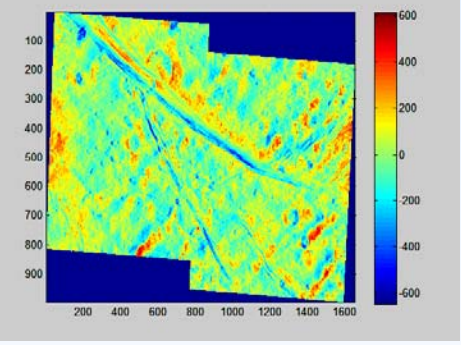
As far as the clutter is concerned, its strength is controlled by statistical parameters of the surface topography. Classical parameters such as root mean square (RMS) height, RMS slope, or correlation length can be used to infer expected backscattering [2].



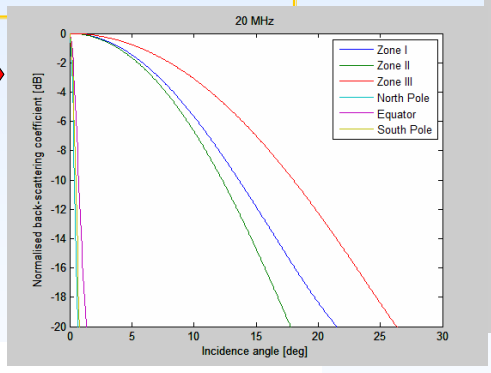
Courtesy of R. L. Kirk (USGS)
LAT -15° LON 120°
Res 600 m
Pixels 1110 x 320

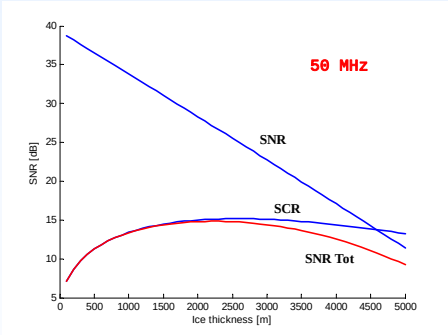
In this work also a fractal characterization of surface will be taken into account, because it has been shown that classical parameters usually employed to describe natural surfaces change when the scale at which the surface is observed changes. Conversely, fractal parameters of a natural surface are independent of the observation scale. The most useful fractal model for natural surfaces is the fractional Brownian motion (fBm), that has also the advantage of having an analytical evaluation of electromagnetic scattering. In both cases, suitable Digital Elevation Models (DEM) of Ganymede are needed.

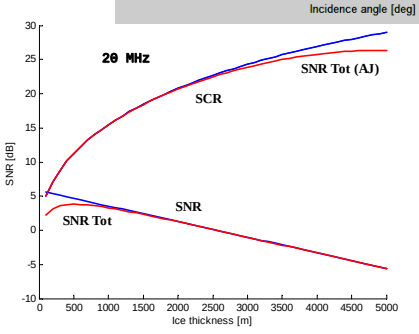
LAT 12° LON 190°
Res. 150 m
Pixels 1134 x 1839



Surface clutter on Ganymede seems to be a much more severe issue with respect to Mars







Final instrument performance can be evaluated by considering classical radar figure such as SNR (including Jovian radiation) and SCR. A model for signal ice attenuation is needed [4] as well as for ice temperature profile [5]

Transmitted power	20 W	20 W	20 W
Central frequency	50 MHz	20 MHz	10 MHz
Transmitted bandwidth	10 MHz		1 MHz
Pulse duration	150 μsec		
PRF	500 Hz		
Antenna	Dipole 0.8 λ		
Ice temperature	**Spohna**		
Attenuation model	**Chyba**		
Eps of ice impurities	**2.4**		
Concentration of impurities	**10 %**		

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