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A high-performance Ka-band transponder for EJSM/Laplace Radio Science Instrument (RSI)

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Abstract

The determination of the gravity fields of Ganymede and Callisto is a crucial scientific objective of EJSM/Laplace, the ESA spacecraft of the joint ESA/NASA mission to the Jovian system. Indeed, in the absence of seismological data, gravity is the method of choice to investigate the interior structure of solar system bodies. Gravity fields are estimated from measurements of the Doppler shift (range rate) in the radio tracking signal caused by accelerations acting on the spacecraft flying close to the body. From these measurements, coefficients of spherical harmonic expansion of the gravity field are derived for geophysical analysis and interpretation in terms of interior structure. If the measurement accuracy is sufficiently high, the analysis of range rate data may also provide the time-varying part of the quadrupole field induced by eccentricity tides.

In order to obtain the best Doppler observables, a Ka-band (32.5-34 GHz) microwave link is required, due to its immunity to interplanetary plasma noise. The key onboard instrument is a Ka-band transponder (KAT), capable of receiving an uplink Ka-band carrier and retransmitting it back to ground with a very high level of phase coherence. The KAT, complemented by suitable ground instrumentation, will establish a two-way radio link characterized by high frequency stability. Range rate measurements to 3 micron/s over 1000 seconds integration times will be routinely achieved for a broad range of solar elongation angles. The KAT will enable also additional measurement types, such as range and open loop recording of a carrier transmitted by NASA's Jupiter Europa Orbiter (JEO).

The device being proposed for EJSM/Laplace builds on the experience gained with the MORE instrument on BepiColombo (ESA) and the KATS instrument on Juno (NASA). However, the definition and architectural design of the KAT has to tackle its survivability in the Jovian radiation environment (the Juno KATS is accommodated inside a protection vault), and stringent requirements in terms of mass, power and volume. Novel technologies, based upon high efficiency GaN semiconductors, are being explored for use in EJSM/Laplace, while mass reduction will be achieved by means of high level of integration among the transponder elements.

The proposed design exploits a combination of dedicated signal processing algorithms and modern technological implementation. The KaT core, based on a digital architecture, leads to the following advantages with respect to a fully analogue solution:

- Optimization of carrier acquisition and tracking performance;
- Inclusion of PN ranging processing capabilities (demodulation and re-modulation);
- Design flexibility with receiver tuning based on programmable constants;
- All-digital modulation capabilities based on Direct Digital frequency Synthesis (DDS).

The performances of the KAT are fully compliant with the tight requirements of the gravity measurements.

The RSI team combines expertise in radio science experiments and precision measurements in space, planetary geodesy and geophysics, and industrial know-how in deep space transponders. Its members are:

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