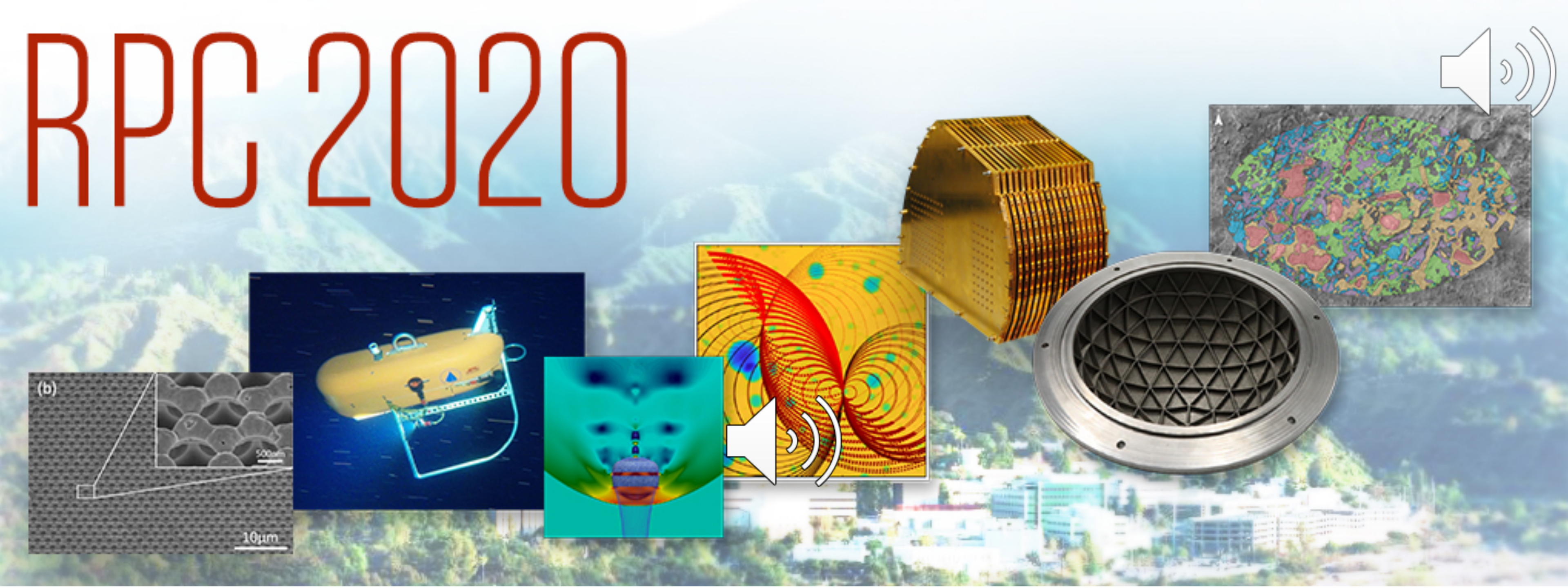

Virtual Research Presentation Conference

NEXT BREAKTHROUGHS IN RADIO METRIC TRACKING

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Program: Strategic Initiative

Assigned Presentation # RPC-284

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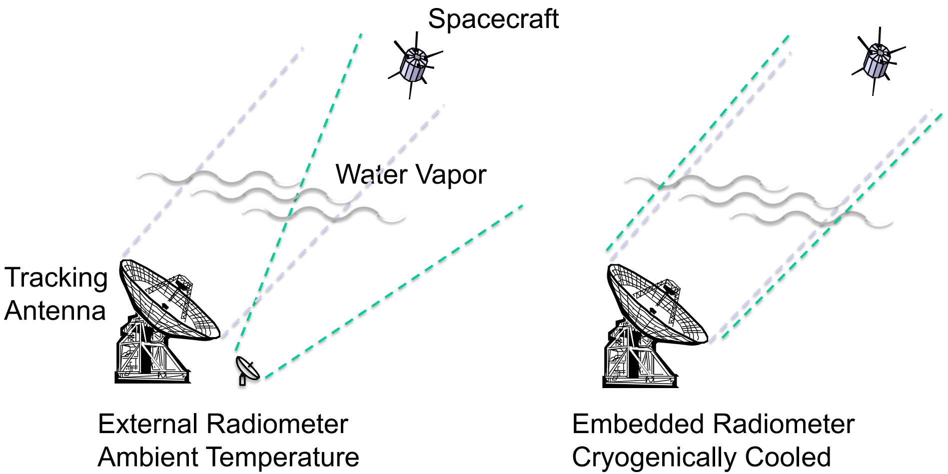
Tutorial Introduction

Abstract

Earth-based Doppler tracking of interplanetary spacecraft is one of the few ways available to determine gravity fields and interior structure of large and small solar system bodies. Resolution of results depends on the Doppler accuracy. Today's best Doppler systems for radio science are limited in accuracy by atmospheric water vapor fluctuations and antenna mechanical noise. Improved tropospheric calibration is needed to improve Doppler accuracy at the short time scales of interest for gravity field science, calling for a water vapor radiometer with better beam matching and higher sensitivity.



Problem Description

a) Context (Why this problem and why now)

Today's space missions are seeking a deeper understanding of the bodies they are sent to probe. Earth-based Doppler is a key method to measure static and time-varying gravity fields. These fields then provide information on interior structure. Knowledge of interior structure is fundamental to the understanding of the formation of the solar system and also for suitability for habitation.

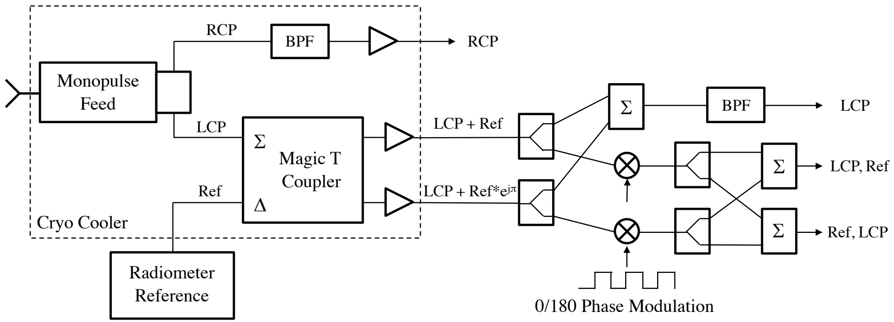
b) SOA (Comparison or advancement over current state-of-the-art)

The current state-of-the-art dates to the late 1990's with Doppler tracking for the Cassini Gravity Wave Experiment. During mission planning it was recognized that water vapor fluctuations would be a dominant error source. Radiometer technology was developed to calibrate this error at the long time scales needed for a gravity wave search. The focus of the current research is to develop radiometer technology that will improve Doppler calibration at the short time scales relevant to gravity field determination.

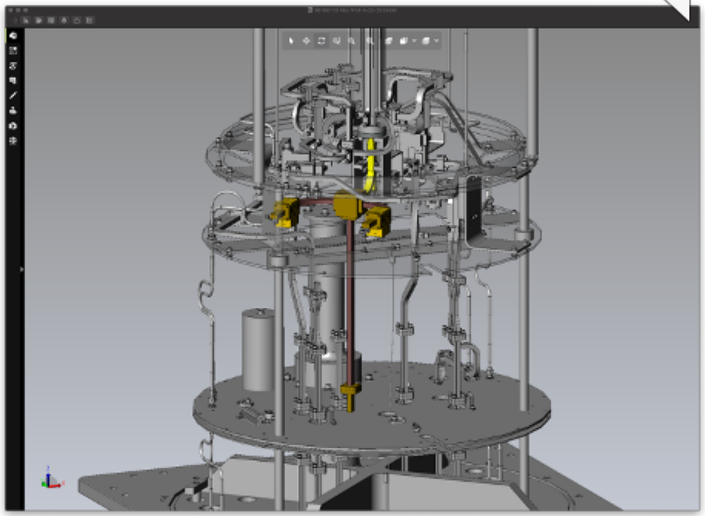
c) Relevance to NASA and JPL (Impact on current or future programs)

The Juno mission's remarkable examination of the Jupiter gravity field will look even better when this radiometer technology is available in the DSN. All radio science investigations relying on Doppler will benefit. Future missions can plan their investigations, e.g. number of spacecraft and mission duration, expecting better Doppler accuracy.

Methodology



A pseudo-correlation radiometer topology is selected for integration into existing XXKa feed package. This design allows the front end cryogenic receiver to simultaneously handle the radiometer (22-32 GHz) and spacecraft (32 GHz) signals without compromising the performance of either system.



Drawing of the XXKa feed showing new radiometer components below the LCP monopulse waveguide. The colored parts are the new wideband polarizer, the Magic T Coupler, and the new wideband LNAs on the LCP side. Waveguide is added to output the radiometer signals through a port to the backend electronics.

Results

a) Accomplishments versus goals

Atmospheric water vapor fluctuations were identified as a key Doppler error source and new technology to improve calibration was developed. A water vapor radiometer was conceived to be embedded in the current DSN Ka-band antenna feed providing better beam matching and higher sensitivity than existing systems. Wideband components to receive both radiometer and spacecraft signals were designed and procured. A bench top prototype was assembled and tested. Drawings were then made to integrate the radiometer components into the cryogenically cooled feed canister.

b) Significance

One of the few remote sensing means for studying interiors of solar system bodies is via the technique of spacecraft precision Doppler tracking by the DSN, which allows measurement of the gravity field generated by an object's mass distribution. In the case of icy moons, the determination of the existence and details of sub-surface oceans is crucial to establishing whether they may be possible habitats for life. For any potential human exploration of small bodies (including Phobos and Deimos), a recognized strategic knowledge gap is their porosity or the existence of interior voids. The embedded radiometer work started here is expected to significantly improve Doppler accuracy and improve science return.

c) Next steps

Task has been extended and XXKa modifications will be done in FY21. If testing is successful this approach will likely be adopted by the Deep Space Network for inclusion in their Ka-band downlink receivers and will be used to improve the accuracy of radio science measurements made with those antennas on all missions they support.

Publications and References

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