An Autonomous Cryobot Synthetic Aperture Radar for Subsurface Exploration of Europa

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We present the design and field testing of a forward-looking end-fire synthetic aperture radar (SAR) for the 'Very deep Autonomous Laser-powered Kilowatt-class Yo-yoing Robotic Ice explorer' (VALKYRIE) ice-penetrating cryobot being developed by Stone Aerospace, Inc. This SAR design demonstrates critical technologies that will support an eventual landing and ice penetrating mission to Jupiter's icy moon, Europa.

This presentation will focus on: (1) design of an array of four conformal cavity-backed log-periodic folded slot dipole array (LPFSA) antennas that form the radiating elements, (2) design of a radar system that includes RF signal generation, 4x4 transmit-receive antenna switching and isolation and digital SAR data processing and (3) field testing of the SAR in glacial melt holes. The antennas have been designed, fabricated, and lab tested at the Center for Environmental Technology (CET) at CU-Boulder. The radar system was also designed and integrated at CET utilizing rugged RF components and FPGA based digital processing.

The antennas are designed to operate within ice while being immersed in a thin (~1 cm) layer of surrounding low-conductivity melt water. The radar back-end uses off-the-shelf electronics and is easy to configure and can be used over a wide frequency range and transmit power levels. The hardware and software programmability of a FPGA based system allows for a very customizable radio transceiver. This capability is leveraged in the design of the SAR system. Field testing of the end-to-end system was performed in conjunction with VALKYRIE tests by Stone Aerospace in June, 2015 on Matanuska Glacier, Alaska.

Results proving the feasibility of an end-fire SAR system using the novel antenna and radar back-end design for vehicle guidance and obstacle avoidance in a sub-surface ice environment will be presented. Data collected by the SAR will be used for constructing sub-surface images of the glacier which can be used for: (i) mapping of englacial features such as crevasses, moulins, and embedded liquid water and (ii) ice-depth and glacier bed analysis to construct digital elevation models (DEM) that can help in the selection of crybot trajectories and future drill sites for extracting long-term climate records.