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Initial Testing of an Airborne Ultra-Wideband Radar Ice Sounder for the Antarctic Ice Sheet

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We have developed a compact, lightweight, high-power, ultra-wideband radar to sound and image ice both in Antarctica and Greenland. The radar operates over the frequency range of 170-470 MHz with a peak transmit power of 1 kW. It is designed to operate with chirp pulse waveforms. The system is designed such that its center frequency, bandwidth, pulse width and pulse repetition frequency can be selected to meet scientific and operational requirements. The system utilizes a 32-element antenna array, with sixteen elements configured for transmit (Tx) and receive (Rx) mounted on one of the aircraft wings and sixteen as receive-only mounted on the other wing. We combined two antenna elements with a power divider/combiner to operate the radar with 8 transmitters and 16 receivers. We also developed compact, lightweight, high-power amplifiers with low harmonic distortion and fast high-power PIN diode Tx-Rx switches for the transmitter. The channels were designed modularly, allowing quick access to electronics and quick swap-out in the field. The chassis includes eight slots for the channels to be slid in and out as necessary with no tools. This feature allows a failed channel to be replaced with a spare within a few minutes during deployment, allowing minimal data loss. We also developed the system to collect data in a Multiple Input and Multiple Output (MIMO) configuration.

The antenna array was modeled to optimize the individual pylons' shape, structure and placement under the wings. Aerodynamic analysis of the pylons was performed using computational fluid dynamic analysis. The aerodynamic loads were then used to perform structural analysis using finite element analysis. This analysis allowed the structure soundness to be verified over different loading conditions and to characterize the dynamic effects under different flow conditions, ensuring the array would have minimal drag while maintaining strong structural integrity.

We integrated the radar system, including the large antenna array, on a Basler aircraft and flight-tested the system in Calgary, Canada, in July 2023. We measured the radar loop sensitivity flying over a lake and verified that the measured loop sensitivity is about 264 dB, within 1 dB of the theoretical estimate. In November and December of 2023, the system was used to measure ice over a grid near Concordia Station. We collected data for 3200 km of survey lines over four days—the system's light weight allowed the plane to fly for much longer during each collection. Initial quick-look echograms have shown a clear view of both the bedrock and the more defined internal layers across the survey, and further processing of the data will show the weaker layers in the deeper parts of the ice. We could also record the surface response, allowing us to map the entire ice profile from surface to bed, which ranged from 2.5 to 4 km thick.

The presentation will provide a detailed system overview, including design, simulations, and laboratory test results. We will also discuss algorithms developed to process data to generate radar echograms. We will present results from measurements over ice in Antarctica.

1. A. Kumar Awasthi et al., "High-Sensitivity Transceiver for Airborne Ultra-Wideband Radio Echo Sounding of Polar Regions," 2022 IEEE Microwaves, Antennas, and Propagation Conference (MAPCON), Bangalore, India, 2022, pp. 1827-1832.