A WIDEBAND RADAR FOR ICE SHEET SURFACE ELEVATION MEASUREMENTS AND NEAR-SURFACE INTERNAL LAYER MAPPING

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Recent satellite observations are showing that the disintegration of the Arctic and Antarctic ice sheets is proceeding rapidly, exacerbated by multiple positive feedbacks. The summer melt area in Greenland has been increasing at a rate of ~40,000 km^2/year since 1992; this trend is somewhat enhanced by volcanic cooling due to the eruption of Mount Pinatubo in 1991. QuickSCAT observations have also confirmed increasing summer melt areas and an increase in the length of the melt season in West Antarctica since 1999. Positive feedback mechanism responsible for the recent acceleration in ice sheet melting can occur on and under the ice sheets as well as in adjacent oceans [4]. Key feedbacks such decreased ice sheet albedo due to surface melting, increased ice stream and outlet glacier velocities due to basal lubrication, and increased iceberg discharge due to loss of buttressing ice shelves have lead to an overall negative mass balance [1] [3].

The mass balance of both the Greenland and Antarctic ice sheets can be defined, in simple terms, as the difference between precipitation, the addition of mass, and the combination of evaporation, runoff, and ice discharge, the removal of mass [6]. All of the processes are directly affected by temperature increases in both air and ocean surrounding the ice sheets. The ocean surrounding an ice sheet is vital to its stability. Recent dramatic increases in anthropogenic greenhouse gases have made the troposphere more opaque to infrared radiation. This increase in opacity has hindered the ability of the atmosphere to radiate heat to space, creating an energy imbalance. This additional energy, sufficient to melt enough ice to raise the sea level by one meter per decade, is mostly absorbed by the ocean. Higher ocean surface temperatures can be linked to higher precipitation rates and the accelerated melting of ice shelves and free sea ice [4].

Many satellite, airborne, and in situ measurements have been taken in an effort to better understand the mass balance of the ice sheets. While satellite missions such as GRACE, ICESat, and Cryosat seek to understand both sides of the mass balance equation, they are only capable of collecting data on relatively low temporal and spatial resolutions [6] [7]. Satellite observations alone are not sufficient to fully understand all mechanism responsible for changes in the overall ice sheet mass balance. Airborne platforms, especially autonomous platforms, allow for larger areas of the ice sheets to be measured with high-resolution remote sensing instruments. These platforms provide more accurate ice thickness estimates, internal layer mapping, and ice-bedrock interface imaging [2].

To address this need, we are designing and developing an ultra-wideband, frequency-modulated continuous-waveform (FMCW), Ku band radar for high-resolution surface elevation measurements and mapping of near-surface internal layers. This radar will be integrated with additional instrumentation aboard an uncrewed aerial vehicle (UAV) being developed at the University of Kansas. The radar is designed to facilitate the generation and transmission of a highly linear chirp with digitally controlled amplitude shaping to correct for distortion introduced by amplifiers and the antenna. The design process will provide a unique radar system with low-range sidelobes and high S/N ratio capable of centimeter vertical resolution. We have modeled the basic system topology using a previously developed prototype radar as an undergraduate senior design project [5]. The new system will improve on the prototype by generating an extremely linear chirp using a fast-settling phase-locked loop driven by a digital chirp generator and a unique, digitally-controlled, amplitude shaping transmission circuit to obtain low range sidelobes We are performing extensive simulations on the system design using Advanced Design System (ADS). These simulations will help to reduce the overall design timeline and provide baseline operating capabilities and limitations.

This radar system will be integrated with at least two additional radars aboard a UAV: an accumulation radar used for mapping internal layers between 10 and 100 m, and a depth sounding radar used for mapping layers below 100 m. Field data collection using these three systems will be performed simultaneously providing high-resolution image of the ice sheet from surface to bedrock. Once these data are analyzed and interpreted, they will be incorporated into global precipitation models to improve the accuracy of ice sheet mass balance forecasts, incorporate the affect of the ice sheets on the global climate, and generate an updated full-sheet accumulation map. The Ku band altimeter provides annual and short-term variation data, the accumulation radar provides medium-term (longer than 5 years) variation data, and the depth-sounding radar provides long-term variation data.

We are designing this radar to operate over the entire Ku band, 12 to 18 GHz, with a transmit power of approximately 1 W, and with range sidelobes of 60 dB or lower. The radar bandwidth and sweep rate are programmable so it is capable of operating one both surface-based and airborne platforms. This paper will present the design, simulation results, and experimental results.

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