An ultra wideband plane wave radar for mapping near-surface isochronous layers

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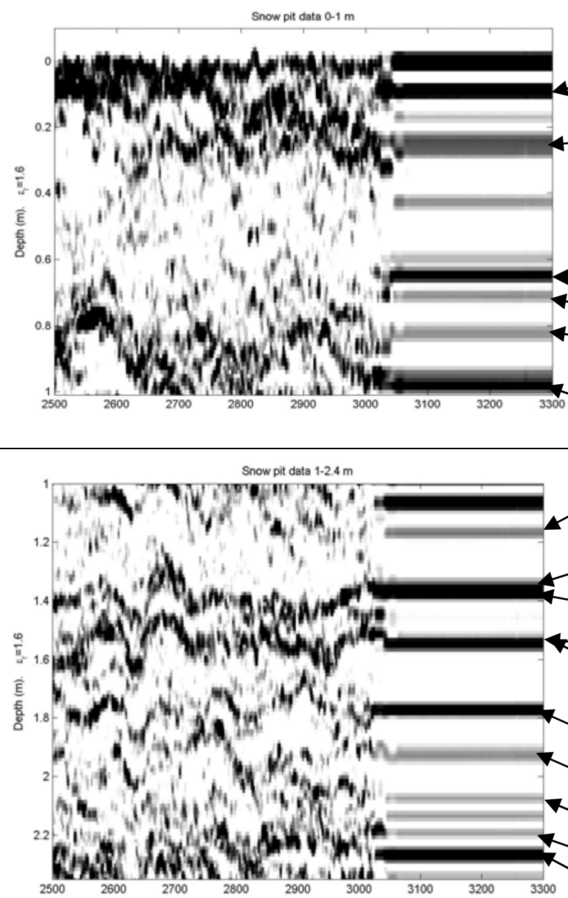
Information on spatial and temporal variation of snow accumulation is required to interpret satellite-based radar and laser surface elevation measurements. To map near-surface internal layers with fine spatial resolution, we developed a 12-18 GHz FM-CW radar to map the near-surface isochronous layers at a resolution of 3 cm and up to a depth of 10 m. We developed the radar to provide plane-wave illumination to a depth of about 10 m using a parabolic dish operated in the near field. The advantage of plane-wave illumination is that weak returns from internal layers are not masked by off-vertical surface scatter, which can occur for radars with traditional antennas. We also developed a sled with a gimbaled antenna mount with a tiltmeter and actuators to ensure that the antenna points at nadir.

The heart of the radar is a fast synthesizer developed using a voltage controlled oscillator (VCO) and phase lock loop with a linear reference chirp for the phase detector. The synthesizer can be swept from 12 to 18 GHz in 500 μs. The phase detector error signal to the VCO was generated by comparing the VCO signal to a highly linear chirp signal from an arbitrary waveform generator (AWG).

We tested our system at the Summit camp, Greenland, in July 2005. We collected a large volume of data along bamboo stakes that were used to monitor snow accumulation. We also dug 3 pits to obtain data on stratigraphy and density. Initial results confirm a high correlation between our data set and the pit stratigraphy. Figure 1 shows a comparison between the two. We used an average density to determine the dielectric constant and thus the velocity of propagation in firn. The solid line at the right side is from stationary measurements at the pit location. We collected more than 200 samples to compare with pit observations. Each sample consists of ten sweeps integrated coherently to improve signal-to-noise ratio. With our system, we can also monitor the spatial variability of the accumulation in a given area. Figure 2 shows layers being tracked over a distance of 150 m.

In this paper we will discuss the design and construction of the radar, as well as provide sample results from field experiments at the Summit camp. We will also show a comparison of experimental data with simulations obtained using density and stratigraphy data. We are also planning to perform measurements with this system at the WAIS divide deep core site during the 2005-2006 field season.



Depth (cm)	Layer type
10.4 – 14	Depth hoar
26 – 29	Wind crust
34 - 35.5	Wind crust
65	Layer (?)
72.5	Wind crust
81.5-83.5	Layer
86-89	Layer (x)
96.5-99	Ice layer
115.5-117.5	Layer
138-139	Layer
140-141	Layer
153-154	Layer
155-156	Layer
180	Ice crust
193	Ice crust
208	Wind crust
217	Wind crust
227-230	Depth hoar

Figure 1. Comparison between radar measurement and pit stratigraphy.

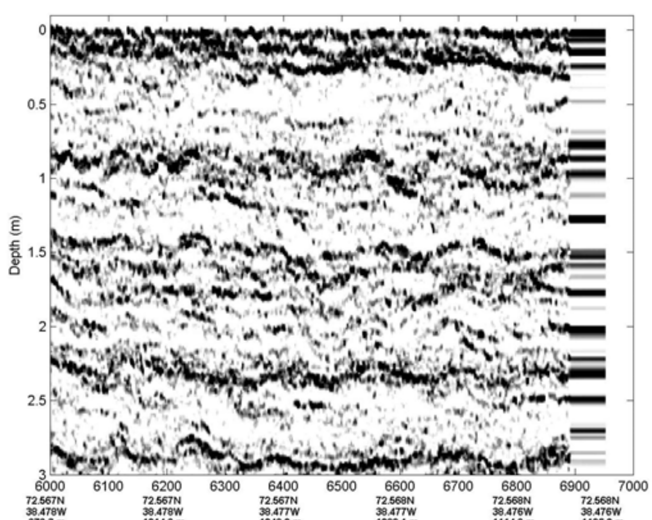


Figure 2. Layers tracked over a distance of 150 m.