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Improvements in the FMCW microwave snow radar

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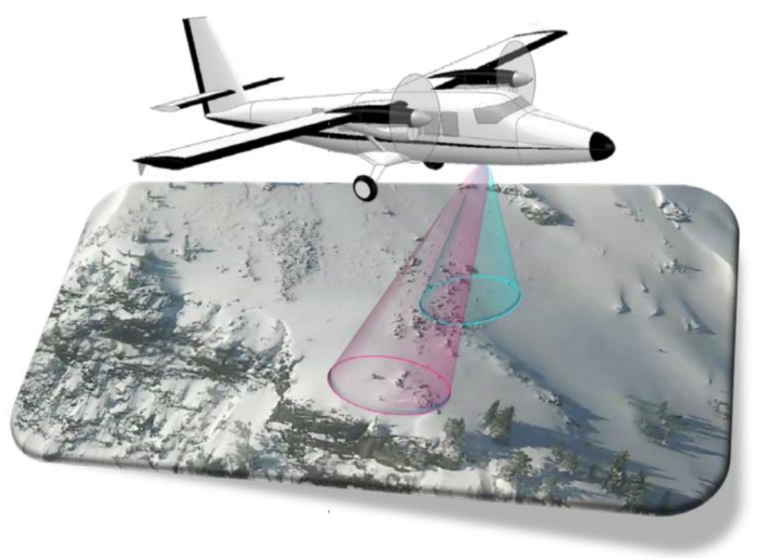

ABSTRACT

This poster addresses the improvements we are undertaking to the new generation FMCW microwave snow radar sensors at the Remote Sensing Center at The University of Alabama. These improvements aim to get a near-ideal impulse response from the newly designed radar systems. These modifications would improve the image quality to observe the interfaces and internal layers of the snow. The cleaner image reduces the post-processing requirements like deconvolution and reduces the time between the data collection and the final product. The system considerations, design, analysis, and results are discussed in the following sections.

INTRODUCTION

We perform airborne measurements of the snow, and the typical products of these type of survey include:

- Snow thickness
- Internal snow layers
- Snow density measurements
- Topographic imaging with off-nadir beam SAR mode

The snow thickness is calculated from the measured propagation time delay between the air-snow and snow-land interface. The detections of the internal snow layers depend on the sensitivity of the sensor system.

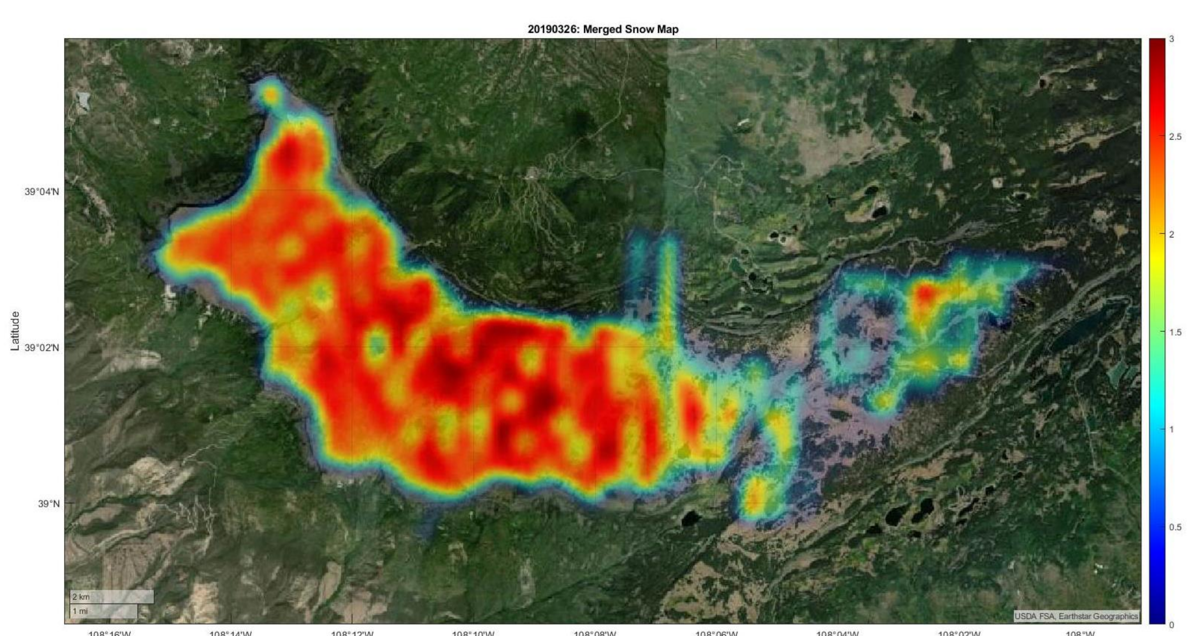

Figure #1 Snow map (March 2019 Grand Mesa, CO)

The operational principle of the FMCW radar is illustrated in Figure 2. A chirp with a linear frequency increase or decrease over a bandwidth is transmitted towards a target. The returned signal in terms of reflection is observed by the receiver. The time delay between these two signals provides us with the impulse response at a beat frequency. The impulse response contains information about the target. The primary target will give us the main lobe, and the trailing edge contains information on the remaining targets.

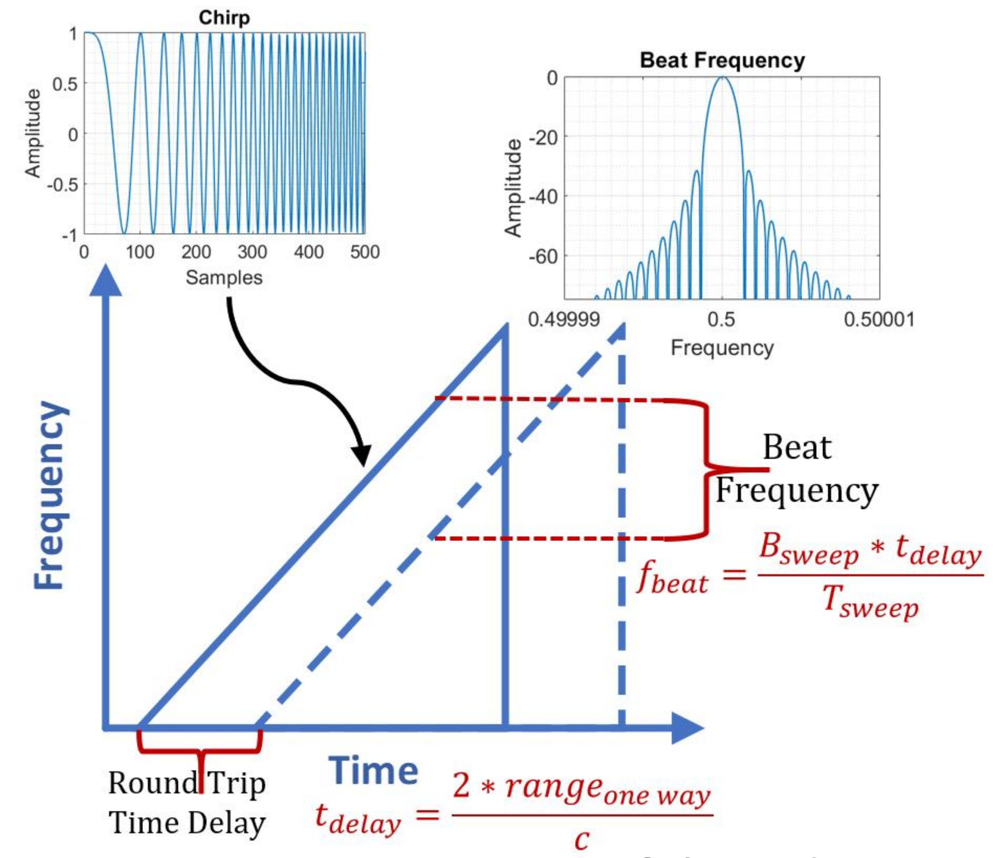

Figure #2 Operation of the radar

IMPROVEMENTS

We operate snow radar in with the Hanning window. The ideal impulse response for the Hanning window has peak sidelobe levels at -31.4674 dB [2]. However, as shown in Figure 3, the sidelobe level for the previous radar is at -22dB. These degradations are typically caused by:

- Internal reflections
- Phase errors
- Amplitude tapering

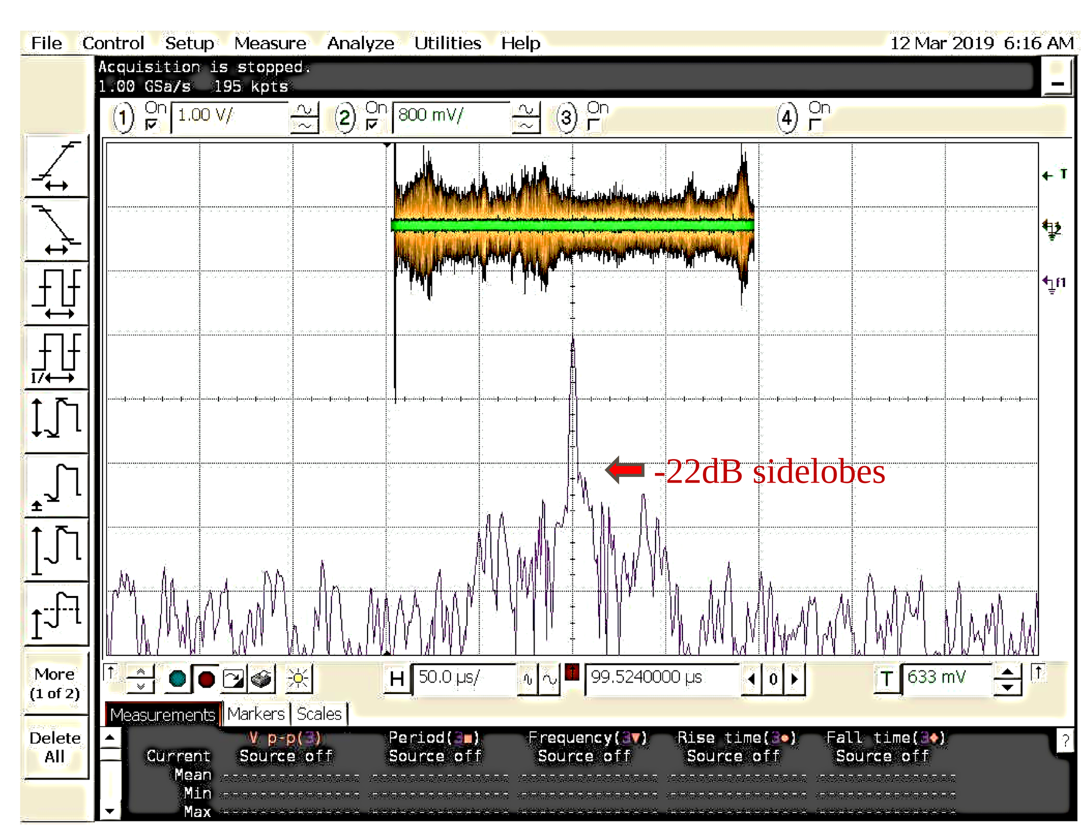

Figure #3 Impulse response of the previous radar

This new radar design attempts to improve this impulse response close to ideal levels with the following steps:

1. Careful design, simulations, optimization, and construction.
2. Minimized primary and multiple reflections
3. Improving chirp linearity
4. Linear and nonlinear system simulations
5. Eliminated connectors and cables

RESULTS

The operating frequency of the radar is 2.7-10.7 GHz, with a chirp length of 180 us and PRI of 230 us. The baseband chirp of 1 GHz bandwidth is up-converted to the 2.5-3.5 GHz and multiplied thrice to get 20-28 GHz signal with an 8 GHz bandwidth. This signal is down-converted with a 30.7 GHz clock to achieve the final 2.7-10.7 GHz chirp. The block diagram of the radar is shown in Figure 4.

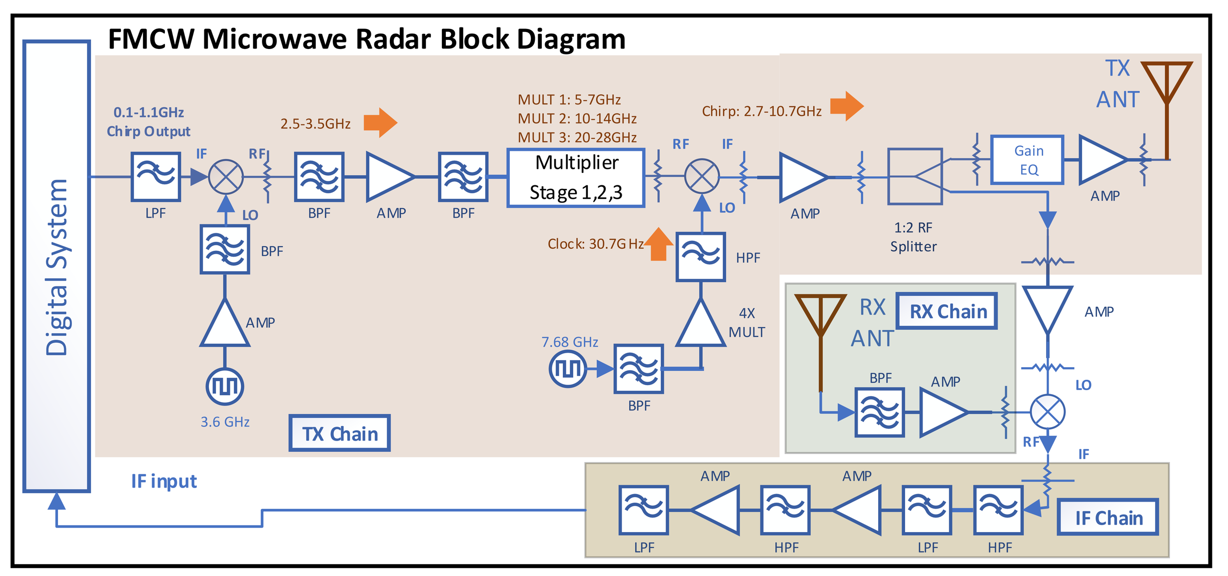

Figure #4 Radar block diagram

A stage by stage reflection analysis was performed to minimize the primary and multiple reflections. Two types of simulations were used to predict the performance of these sections:

1. Transient Simulations
- Checking system beat frequency/impulse response
- Identifying unwanted peaks/sidelobes and resolving them

2. Harmonic balance simulations
- Identification of harmonic levels, inter-modulated products, and noise floor levels
- Suppression of unwanted products
- Keeping unwanted products lower in the passband

Figure 5 shows one such result for a system simulation.

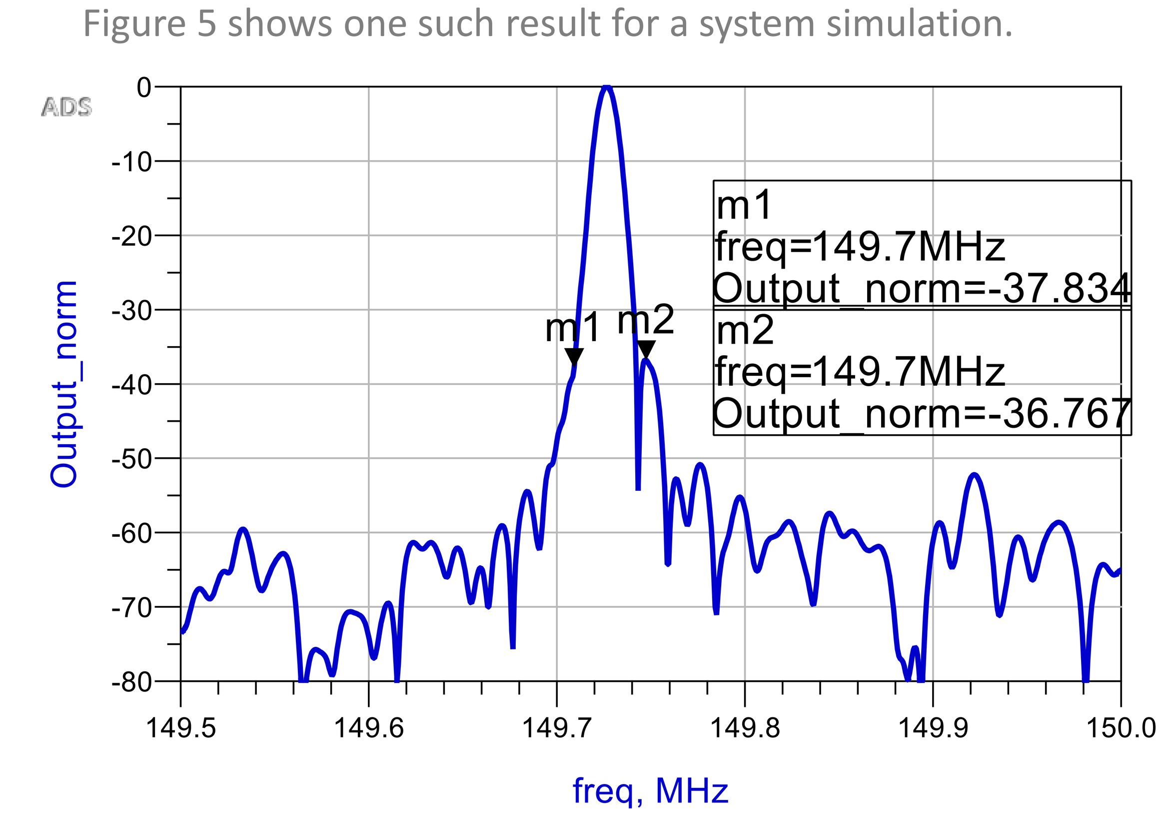

Figure #5 Current System Simulation Output

These improvements in the hardware section of the system will offer the following advantages:

a) improved image quality
b) improved sensitivity
c) avoids deconvolution and eases signal processing requirements with cleaner layer image
d) reduced time to get the final processed data
e) beam steering with multichannel for better performance of mapping features on slope/ different geographical features
f) cleaner image helps with easing constraints of machine learning, which will auto-detect the interface layers

This improved radar performance will help to do near-real-time data processing and generate results within 4-6 hours after a survey flight.

CONCLUSIONS

The new FMCW microwave snow radar is in the advanced stage of development. The extensive linear and nonlinear system simulations and analysis has contributed to the identification of degradations caused by various system parts, and the remedies have been applied. This improved radar performance will aid in signal processing and reduce the time needed to get final data products.

We are eagerly looking forward to the next field deployment to test these systems.

REFERENCES

[1] J. Yan et al., "Airborne Measurements of Snow Thickness: Using ultrawide-band frequency-modulated-continuous-wave radars," in IEEE Geoscience and Remote Sensing Magazine, vol. 5, no. 2, pp. 57-76, June 2017, doi: 10.1109/MGRS.2017.2663325.
[2] Catalog of Window Taper Functions for Sidelobe Control, SANDIA REPORT SAND2017-4042, Page Number: 41, 69
[3] Aerial survey image, S. Yan (2016)