A Simulation Study of the Imapct of Surface Clutters on Spaceborne Precipitation Radar Sensor

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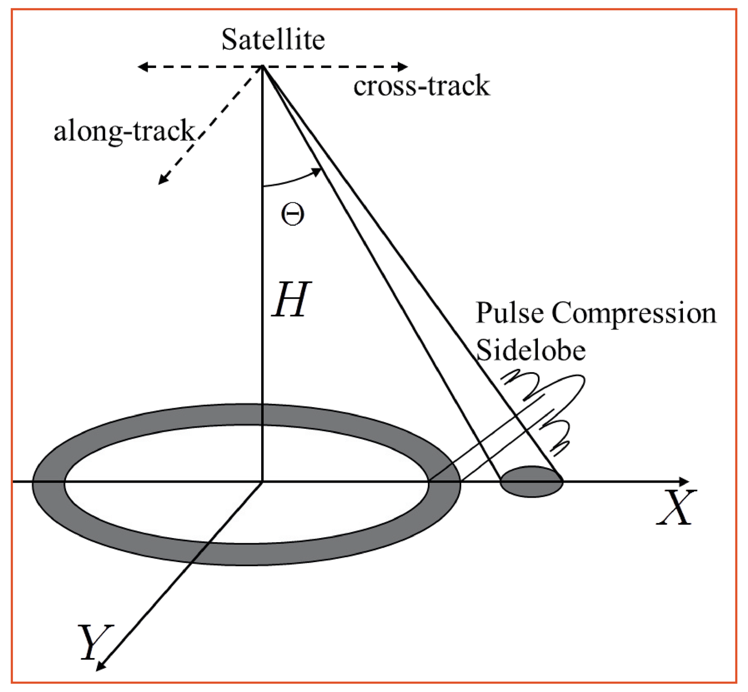


Figure 1: Spaceborne weather radar geometry

Introduction

Spaceborne atmospheric radars have been the key source of knowledge of the earth's climate and global water resource (Levizzani (2007)). The challenge of quantifying radar system performance is exacerbated by factors such as thermal noise, finite receiver bandwidth, nonlinearities of the system and the interference/clutter from earth's surface. To address these challenges, accurate sensor simulation plays an essential role (Pavone (2000)). This study focuses on surface clutter echoes through antenna and range sidelobes from pulse compression. Pulse compression receiver modeling is incorporated into existing radar clutter model to provide a tool to quantify system performance in the field of sensing the near-surface weather phenomena. Simplified antenna pattern and pulse compression filter response models are used to investigate the worst case scenarios with reduced computation requirements. The parameters are mainly based on existing TRMM, but waveform parameters used in HIWRAP system is also included as tabulated in Table1. The radar geometry is depicted in Figure1.

Height	350 km
Frequency	13.8 GHz
Scan Angle	17° with 0.71° step
Transmit Power (P_t)	616 Watts
Antenna Gain (G)	47.4 dB
Antenna main beam width	0.71°
Rectangular pulse width	1.67 µs
Rectangular Pulse Resolution	250 m
LFM pulse width (τ)	20 µs
LFM Band sidth (β)	2 MHz

Table 1: Radar Configuration

Models

In this study, antenna pattern is modeled as Gaussian shaped main beam with flat sidelobes as shown in Figure 2. Though simple, this model provides worst case performance benchmark. Surface clutter interference exists where distance of radar range gates are close to or greater than height of satellite. A better prediction of backscattered power would lead to more realistic simulations. For land surface, model proposed by Morchin (1990) is used while for sea surface model provided by Hanado and Ihara (1992) and Meneghini and Atlas (1986) are used. The models are depicted in Figure 3 and Figure 4 respectively.

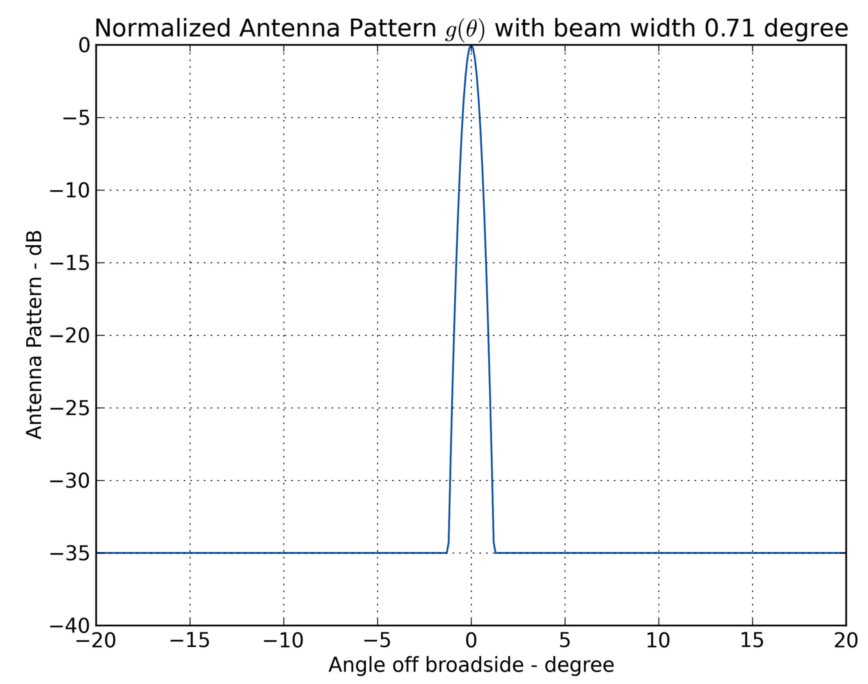


Figure 2: Normalized Antenna Pattern

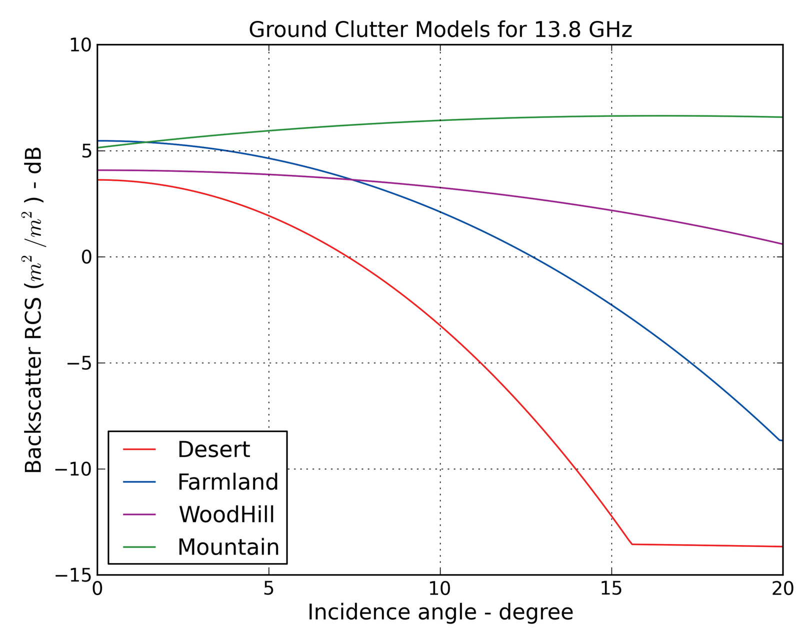
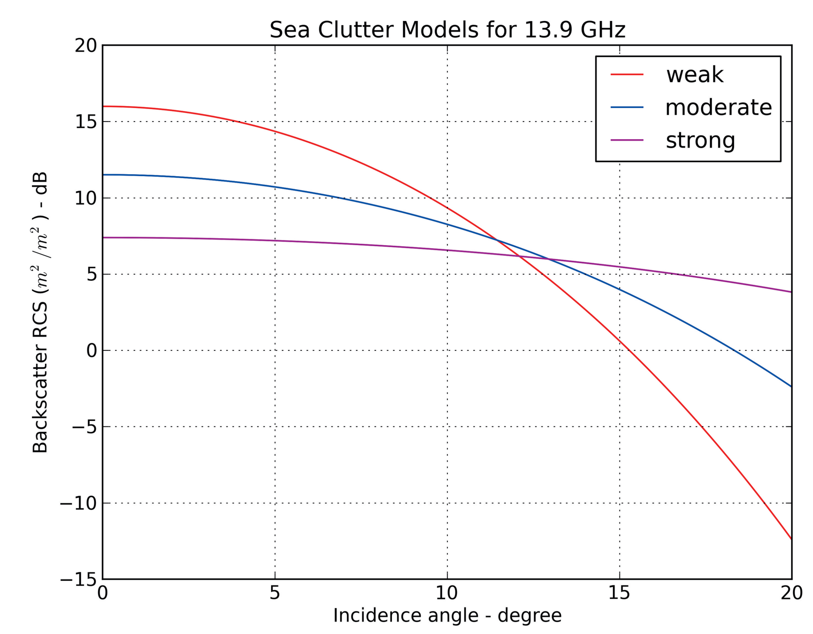


Figure 3: Ground Clutter Model



Figure

Results

Sea clutter return, without pulse compression, for weak and strong wind condition (strong wind case shown in Figure 5) match very well with the published actual measurement data (Durden (2001)) and Hanado and Ihara (1992).

The white area is clutter free area and dark blue is the sidelobe clutter area. *The reason for "saw tooth" structure is due to the fact that the range bins are not parallel to the ground as the beam scans off nadir.* Surface clutter returns through antenna and pulse compression sidelobe for sea surface with weak condition for sidelobe level -40 dB and -60 dB are illustrated in Figure 6 and 7 respectively, and for land (desert) in Figure 8 and 9. As can be seen, interference increases to about 3km at nadir due to range sidelobe (related to LFM width). The clutter power is much lower for -60 dB sidelobe level.

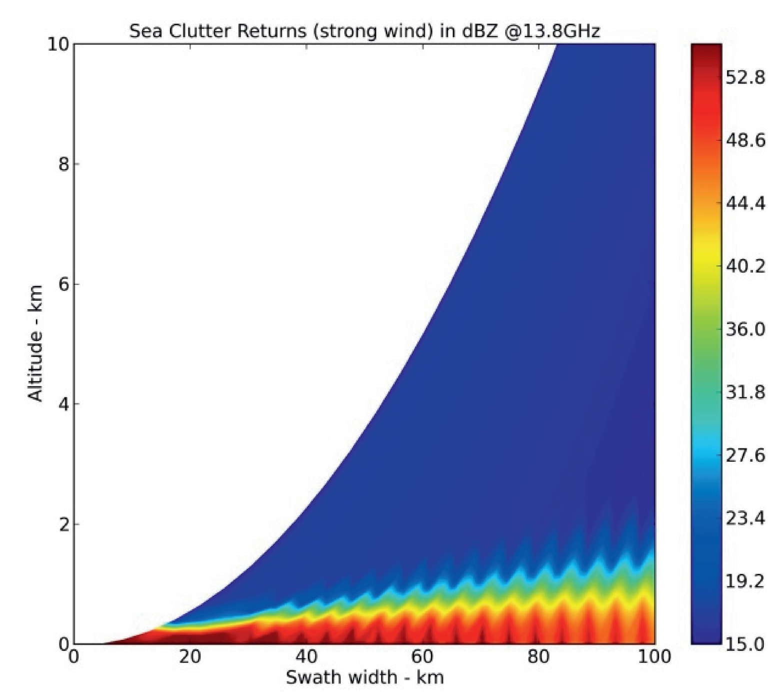


Figure 5: Sea Clutter return with strong wind without pulse compression

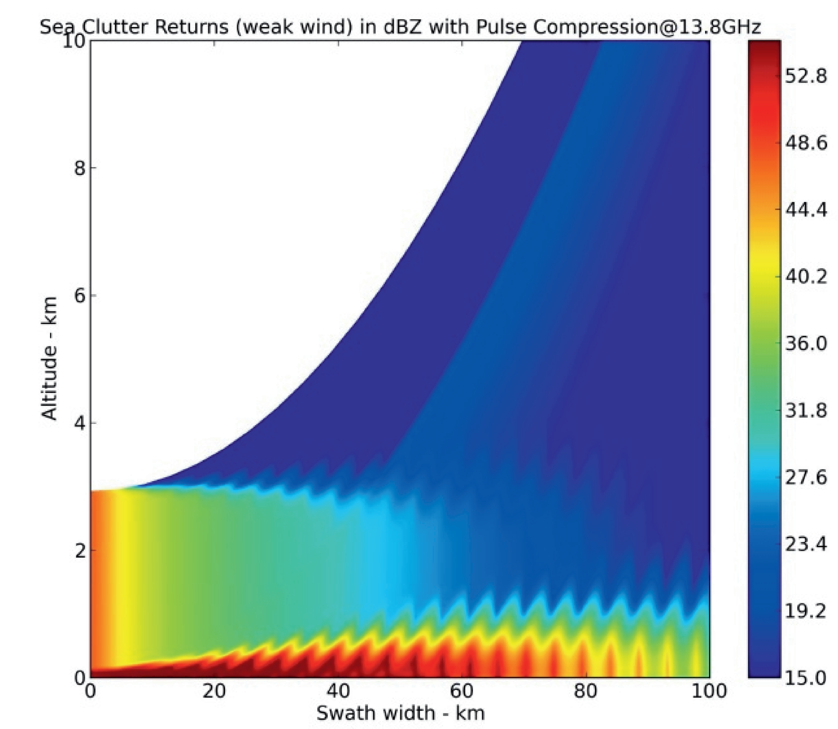


Figure 6: Sea Clutter return with weak wind with pulse compression @ -40 dB sidelobe level

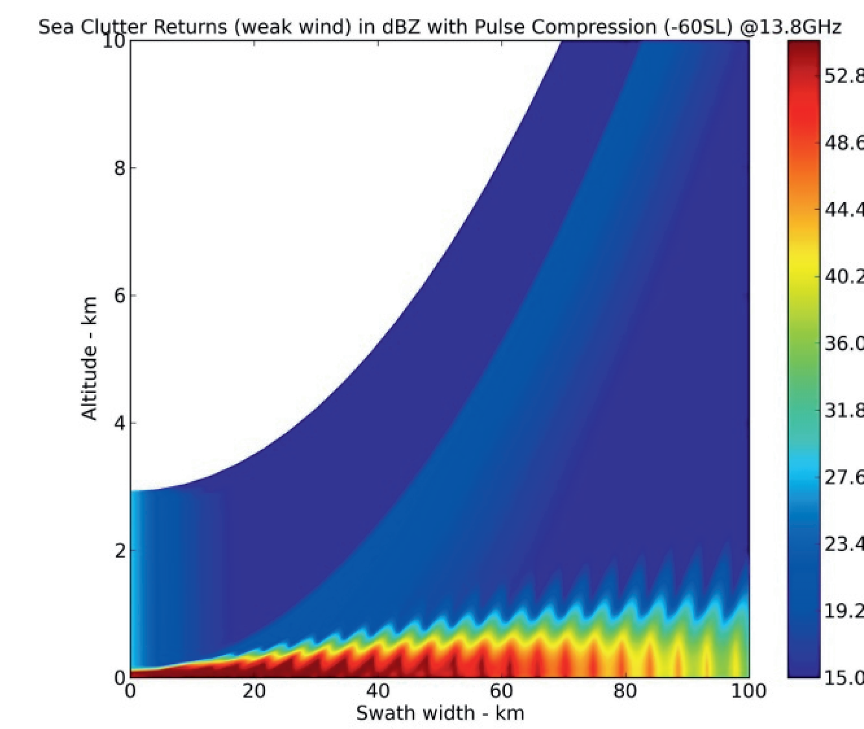


Figure 7: Sea Clutter return with weak wind with pulse compression @ -60 dB sidelobe level

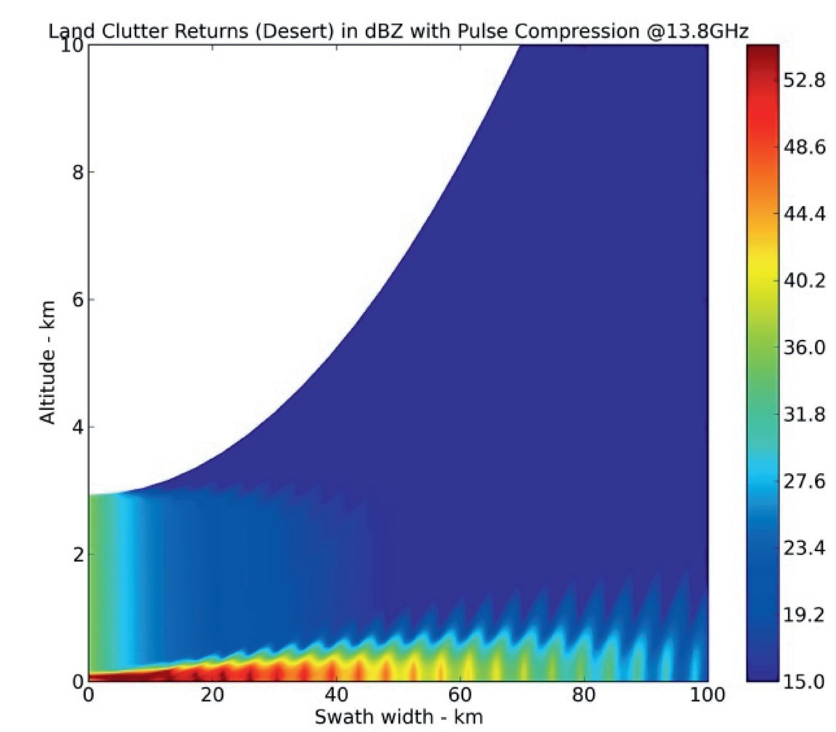


Figure 8: Land Clutter return (desert) with pulse compression @ -40 dB sidelobe level

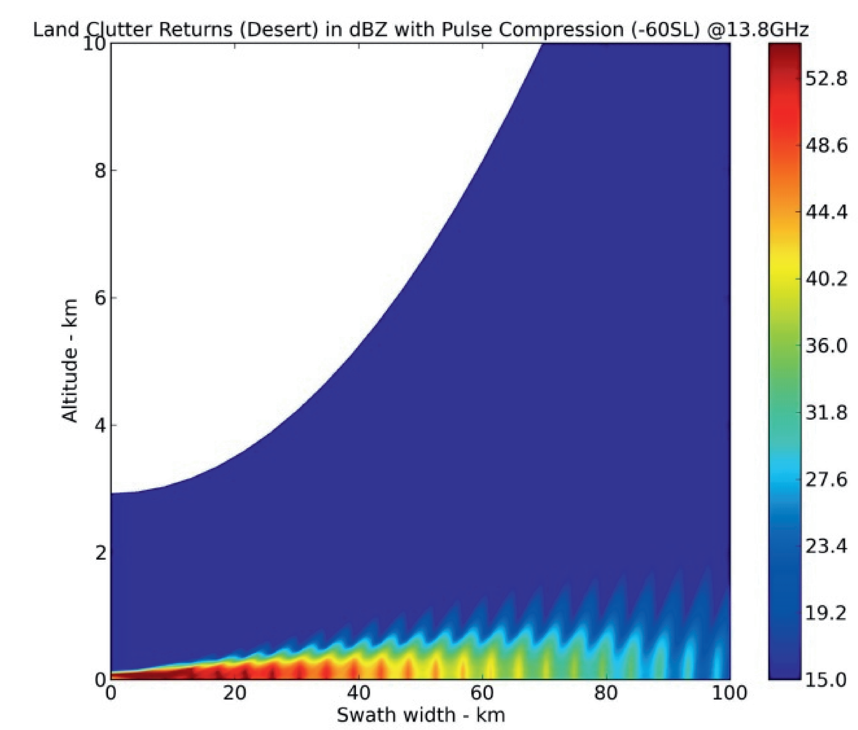


Figure 9: Land Clutter return (desert) with pulse compression @ -60 dB sidelobe level

Conclusions

- Surface clutter echoes through antenna sidelobes and range sidelobes from pulse compression can severely interfere with the atmosphere returns near the earth surface of spaceborne weather radar.
- For 40 dB range sidelobe level, intense interference larger than 35 dBZ is observed anywhere lower than 1.5 km.

Future Work

The spaceborne radar simulator will be further extended to include different system losses and power amplifier nonlinearities. Practical antenna pattern and pulse compression filter response will also be incorporated. This will be feasible as a simulated weather field at fine scales over various atmospheric conditions has been made possible by advanced numerical weather models (Zhengzheng (2011)).

This work is supported by NASA EPSCoR grant NNAX11AM10A. The authors would like to express sincere appreciations to the researchers and engineers at NASA-GSFC.

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