Clutter Power Spectral Density Generated Using the Camber Radar Toolkit™

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September 12, 2002

Abstract

A software application designed to predict the Power Spectral Density (PSD) of airborne radar clutter is described. The application is built with the Camber Radar Toolkit™ and can be used to drive a radar stimulator for hardware-in-the-loop testing.

Introduction

The real-time availability of the airborne radar Power Spectral Density (PSD) has potential applications in the evaluation of target detection and other radar performance. In order to determine the PSD of an area, a geographic database (i.e., landmass) of the area of interest is required. This can be created from elevation data, such as that available from the National Imagery And Mapping Agency (NIMA) Digital Terrain Elevation Data (DTED), and cultural data, such as the NIMA Digital Feature Analysis Data (DFAD). The DTED data is a gridded database and the DFAD is a vector database. We combine these together using commercially available editing tools to produce a landmass database in the OpenFlight format, an industry-standard format hierarchial database of polygonal data with associated attributes. That is, a collection of triangles with radar reflectivities.

We use the Camber Radar Toolkit™ (RTK) to process the landmass database and create realistic radar clutter signals. The RTK is a widely used software suite that provides real-time simulated radar signals for many airborne radar modes including real-beam ground map, Doppler beam sharpening, and synthetic aperture radar modes.. The software is used for integrated aircrew training and simulation devices, as well as for standalone engineering development and radar desktop training applications. Presently, over 100 training devices are in operation using the RTK as a basis for the radar simulator subsystems.

We made modifications/additions to the RTK for this application. The RTK was used as the front end of the application to maintain the landmass, sample the landmass, and form range traces of the terrain related to the radar clutter signal. Then we added back end processing, such as computation of range/Doppler, to create the PSD.

Application

The RTK was used as a starting point for this application because it provides a collection of real-time landmass database paging algorithms which allow ground characteristics (such as terrain height and reflectivity) to be efficiently encoded and sampled. Backscatter return algorithms are used to determine the intensity and characteristics of reflected energy received from radar transmission. The RTK also provides a library of functions which are used for efficient numerical processing and re-use of individual azimuth samples. Perhaps most importantly, the RTK allows quick tuning of radar and simulation parameters for evaluating multiple scenarios or radar configurations.

The Clutter PSD algorithm uses multiple azimuth samples to represent the relevant extent of the antenna beam pattern. The number of samples to be used and the spacing of the samples are chosen so as to provide satisfactory azimuth coverage and sufficient azimuth resolution to support the frequency resolution desired. Closure rate for each range/azimuth element is computed by determining the angle between the velocity vector and the line-of-sight to the element. The actual Doppler shift can then be determined using transmit wavelength. The return is then categorized into one of a discrete number of frequency bins, selected to span the unambiguous frequency shift domain determined by the radar pulse repetition frequency (PRF). The return is also categorized into one of a discrete number of range bins, selected to cover the unambiguous range domain (also determined by the PRF). Lastly, the returns are “wrapped” in range and frequency to indicate ambiguous returns.

Results

Two-dimensional PSD plots using typical low-PRF radar and aircraft parameters follow. The plots are color-coded to indicate the power levels of the returns and the levels are 10db. We have normalized the frequency of the plots by assuming that the radar receiver mixes the radar signal to zero frequency at the maximum range. Note that the frequency offset due to change in Doppler with decreasing range is apparent in some of the plots. Note also that the first null of the radar antenna pattern is clearly discernable in some of the plots.

These plots are for an area surrounding Albuquerque, NM. The first four plots show the change in PSD with antenna pointing angle. The last plot shows the effects of radar shadow.

For these plots, an antenna azimuth sample spacing of approximately 0.072 degrees was used, with a total beam coverage of over 10 degrees. 143 antenna azimuth samples were used in the beam, giving more than enough resolution to handle the 128 frequency bins. For other selections of PRF and frequency resolution, this number may be adjusted.

For applications where even greater frequency resolution is needed, an interpolation algorithm may be implemented, allowing for a reduction in the actual number of azimuth samples while maintaining complete coverage of the frequency spectrum.

All plots were generated on a dual-processor Pentium II running Windows 2000. The Camber Radar Toolkit™ is also available for the Linux and Irix operating systems.

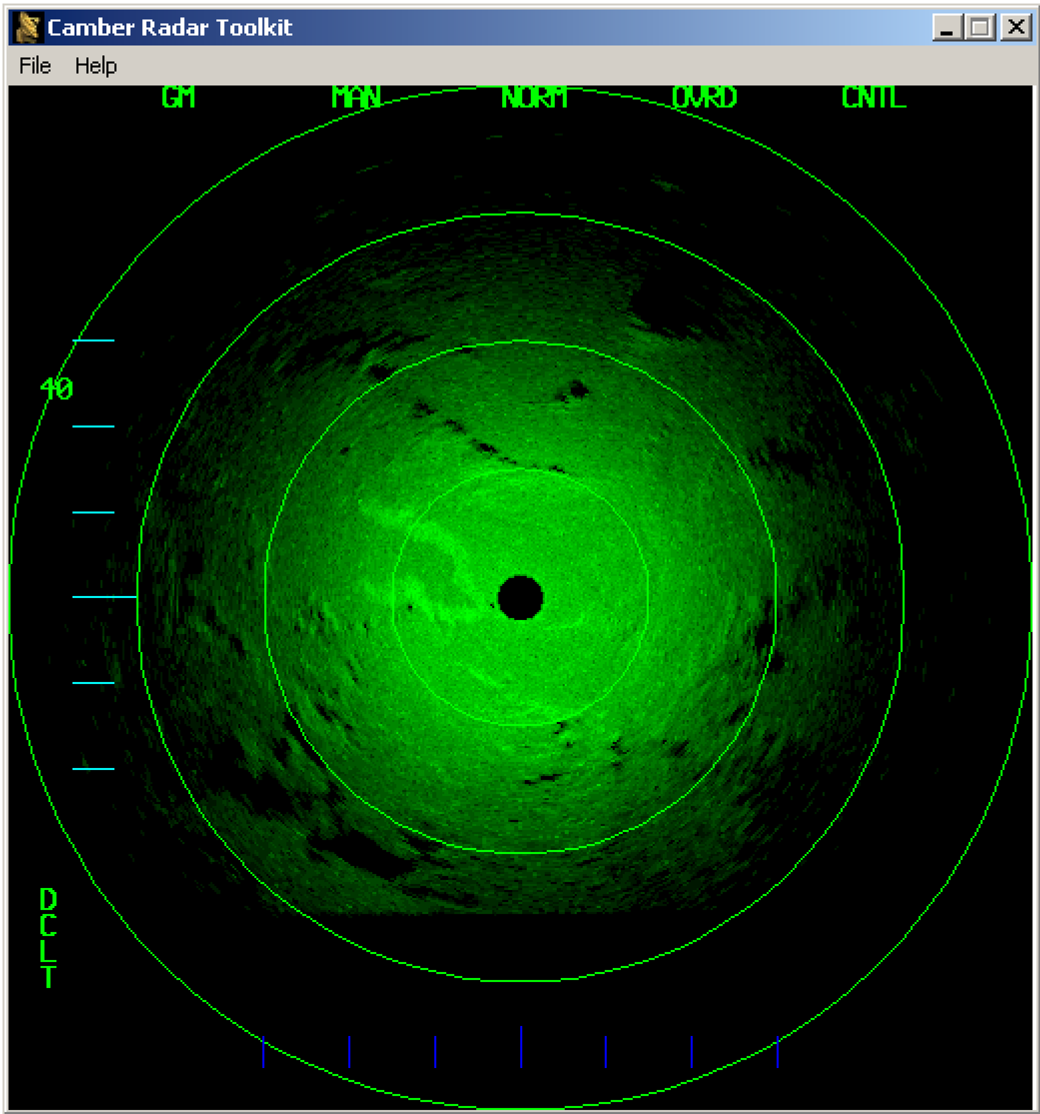

Figure 1. Radar PPI Display, 40 nmi range scale. The aircraft is 20nmi southeast of Albuquerque, flying east, and about 11,000 ft above the terrain. Note that there are few radar shadows. The first four PSD plots were obtained from this scenario.

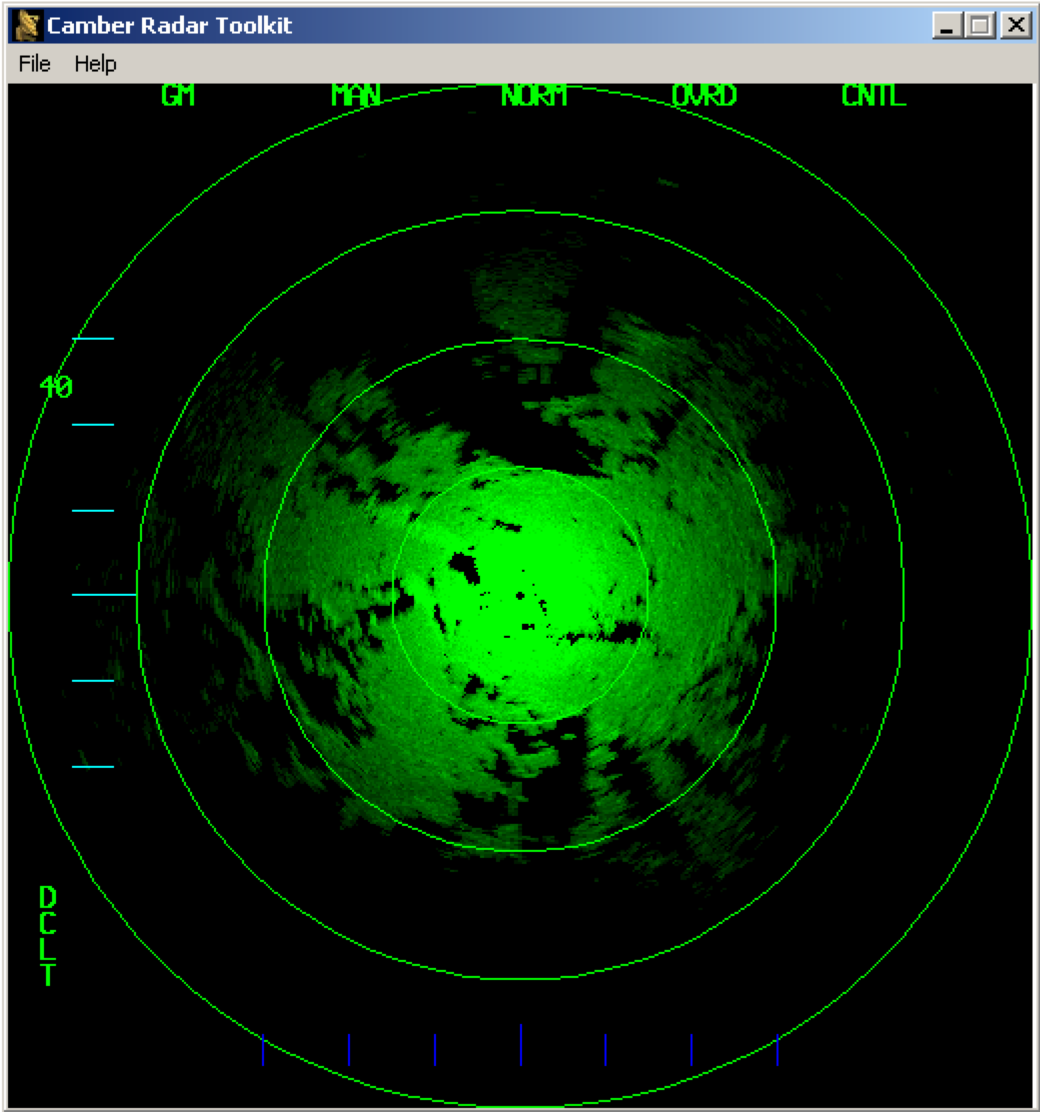

Figure 2. Radar PPI Display, 40 nmi range scale. The aircraft is 20nmi southeast of Albuquerque, flying east, and about 2,000 ft above the terrain. Note that there are many radar shadows. The last PSD plot was obtained from this scenario.

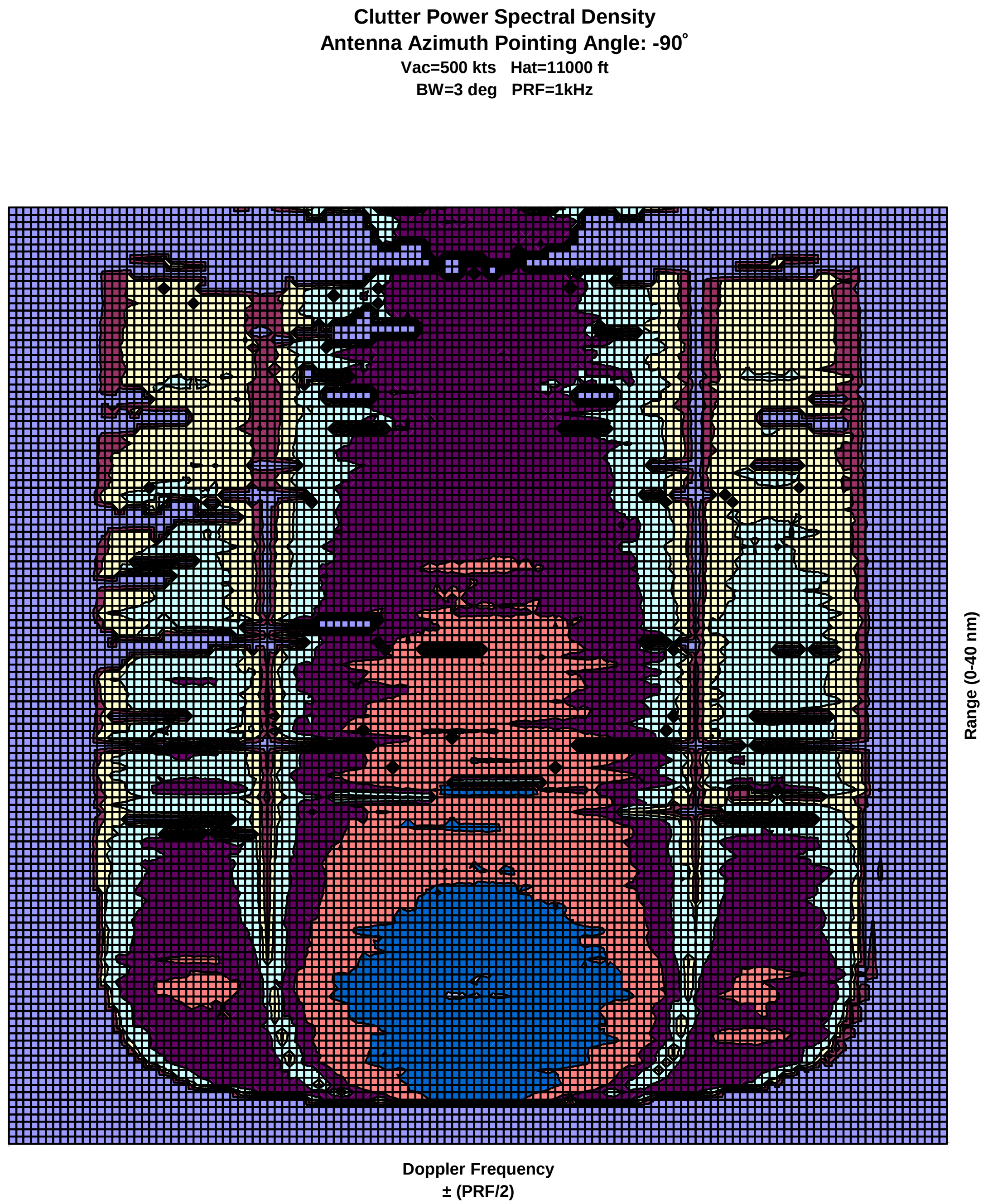

Figure 3. Clutter PSD with antenna pointing broadside. Note that the PSD is centered about zero and is very broad, nearly 800 Hz in extent. The blank area at the bottom of the plot is the altitude hole.

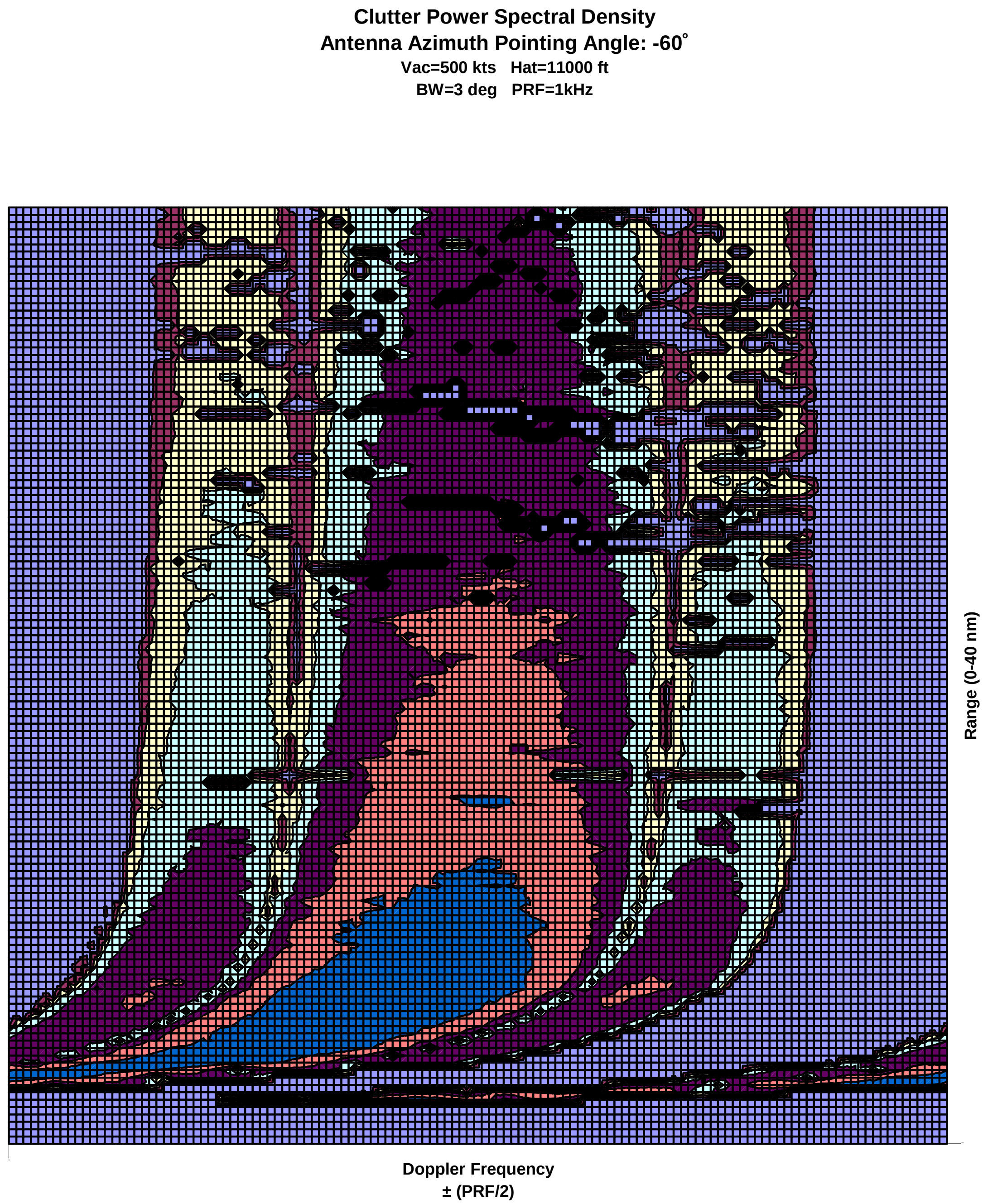

Figure 4. Clutter PSD with antenna pointing -60 deg. Note that the PSD becomes skewed to lower (i.e., negative) frequencies at near range due to lookdown angle and that there is some frequency ambiguity at very short range.

Figure 5. Clutter PSD with antenna pointing -30 deg. Note that the PSD becomes narrower. The two narrow vertical bands represent the antenna azimuth first nulls.

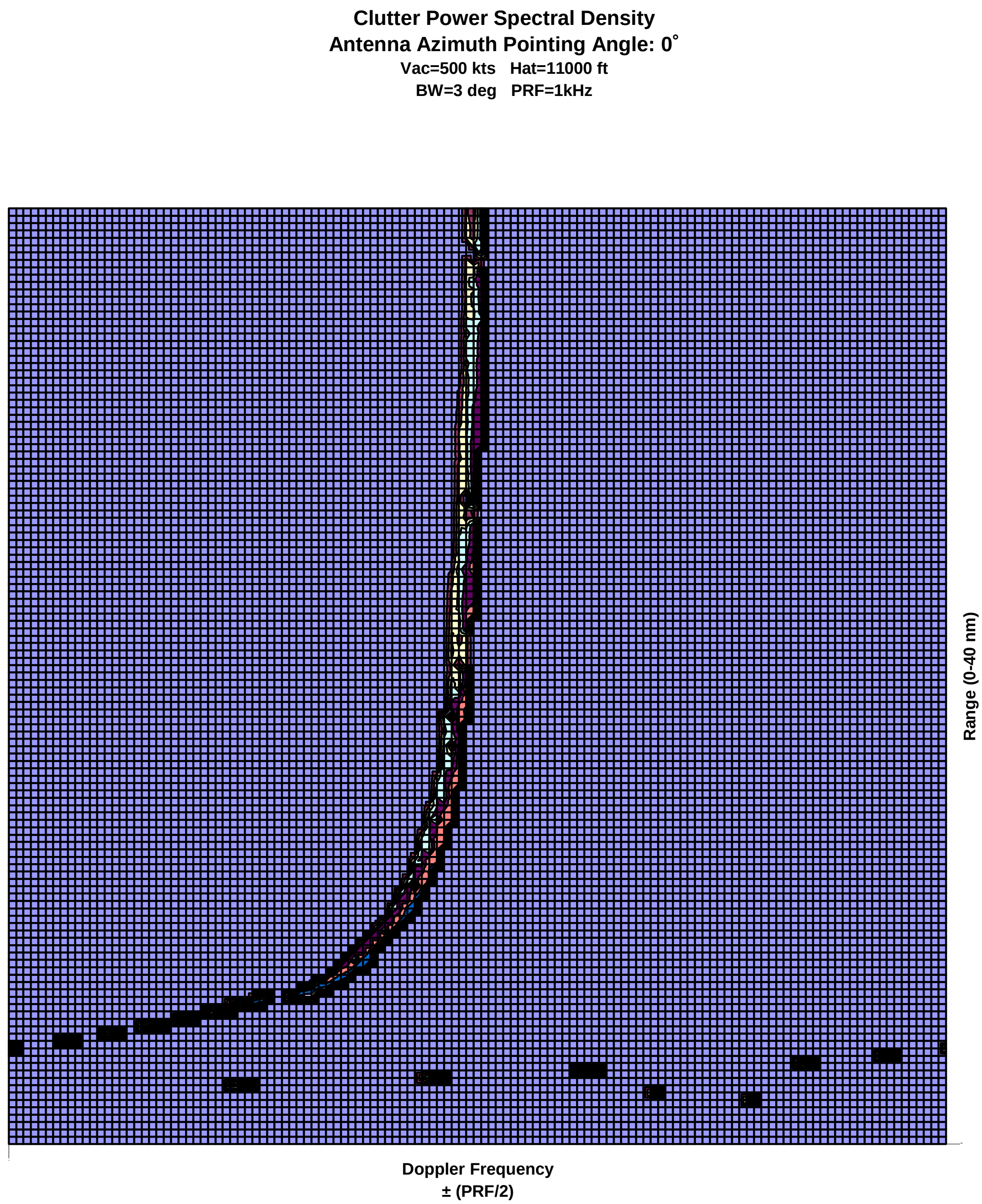

Figure 6. Clutter PSD with antenna pointing along the heading vector. Note that the PSD becomes very narrow, but is very skewed at near range.

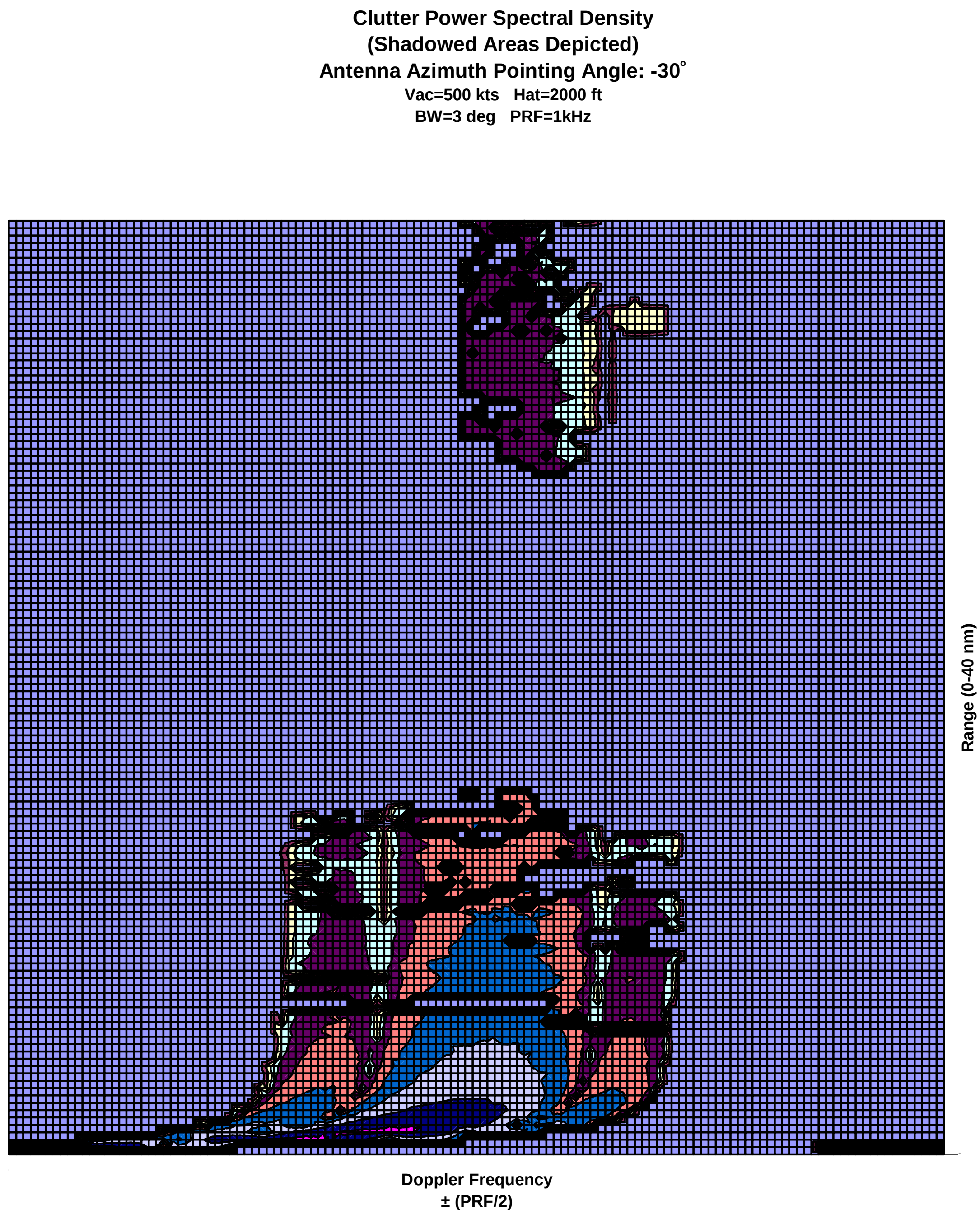

Figure 7. Clutter PSD with antenna pointing -30 deg and the aircraft at much lower altitude. Note that the PSD now indicates a very large shadow where the Sandia Mountains pass across our flight path about 15nmi away.

Summary

We have demonstrated an approach to generating radar clutter PSD with the Camber Radar Toolkit™. This data can be provided in real-time in a format suitable for driving a radar stimulator.