An Improved Visualization Of Mini-RF Bistatic Targeting Geometry. R. T. Poffenbarger[1], F. S. Turner[1], B. R. Jensen[1], G. W. Patterson[1], C. M. O'Shea[1], R. C. Espiritu[1], [1]Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Rd, Laurel, MD 20723 (Ryan.Poffenbarger@jhuapl.edu)

Introduction: The Miniature Radio-Frequency instrument (Mini-RF) onboard NASA's Lunar Reconnaissance Orbiter is a synthetic aperture radar (SAR) [1, 2] that, in coordination with either the DSS-13 Goldstone Deep Space Communication Complex or the Arecibo Observatory, operates in continuous receive mode to conduct bistatic S- and X-band radar observations of the lunar surface [3, 4].

Mini-RF planning operations are a multi-step process involving the management of orbital constraints (will Mini-RF be able to see the target?), radar constraints (will Mini-RF be able to see the target *well?*), flight constraints (will the observation violate any spacecraft system constraints?), and scheduling constraints (will other instruments and the ground station be able to accommodate this observation?). The analyses of orbital constraints, flight constraints, and scheduling constraints are typically straightforward in the sense that the associated "keep out zones" are more easily quantified and explicit. Whereas the limiting radar constraints (i.e., pulse repetition interval (PRI) and spacecraft attitude) can vary significantly from collect to collect and these variations can affect the quality of processed data. Here, we will focus on an improved visualization of observation opportunity radar geometries to improve the planning decision process and, as a result, improve data quality.

The Ground Station/Mini-RF Bistatic System: When operating in support of a Mini-RF observation, the ground station transmits pulsed signals with pulse repetition interval as requested by the instrument team. The transmitted pulses are backscattered from the lunar surface and received by the Mini-RF antenna. The PRI chosen for data collections influences the locations of range and Doppler ambiguity contours that, in turn, constrain potential radar imaging geometries. Adjusting the LRO spacecraft attitude provides a degree of freedom to navigate that constraint and doing so will influence the Mini-RF antenna footprint (for a given power level) and the positions of the antenna sidelobes.

Modeling of The Antenna Footprint and Sidelobes: Using a simple representation of Mini-RF's antenna pattern and the spacecraft geometry, we can use root-finding to solve for its footprint given some cutoff power level. We currently model the first sidelobes of the backscattered signal as points of an arbitrary size. The positions of the sidelobes are an important consideration for the Mini-RF planning process, though. Knowing the location of the sidelobes is valuable in determining an appropriate spacecraft attitude for avoiding "ghosting" or heightened ambiguity in the processed image due to the increased power of the sidelobes. This typically manifests itself in the processed image as a geologic feature which falsely repeats itself, as seen in Figure 2. A more accurate representation of the effect of sidelobes on the planning process could be realized using the same root-finding approach as for representing the antenna footprint.

Modeling of Range and Doppler Contours: For the series of pulses centered about target time/location we have drawn contours that show where on the surface backscatter would be ambiguous in range or Doppler with the target point. A range contour shows where backscatter from pulses other than the reference pulse will arrive at the same time as the reference pulse backscatter. In a similar vein, the Doppler contours show where backscatter from pulses other than the reference pulse are shifted in frequency such that it cannot be distinguished from the reference backscatter's frequency.

Direct Path and Forward Scatter Interference: The direct path is the signal reaching the spacecraft directly from the ground station before scattering on the surface. While this signal is important as a phase and timing reference during processing [5], it can affect data quality if the direct path from preceding and following pulses are allowed to illuminate the spacecraft at the same time as backscatter from the reference pulse. We model this as its own unique contour that should be kept away from the antenna pattern. Similarly the forward scatter, which is the specular reflection of the spherical moon, is drawn per pulse. This now covers the major components of the current radar planning diagram as is exampled in Figure 1.

An Improved Visualization of Ambiguity: As an improvement to the "contour" approach to Doppler and range ambiguity, we introduce an algorithm for quantifying the net ambiguity of each pixel (at some arbitrary resolution) inside the antenna footprint. We can construct this gridded antenna footprint by considering the power returned from each individual pixel inside the footprint relative to the power returned from their respective sources of ambiguity (range/Doppler aliasing, direct path, forward scatter). This is uniformly better than the contour approach in determining a viable radar geometry, since the contour approach by nature only considers ambiguities relative to the target point. Observations where the quality of the target point is not necessarily prioritized over the image as a whole, as is often the case for mare observations, would benefit most.

Instead of focusing on the "limits" of different radar parameters (bounds of some power level, location of sidelobes, location of ambiguities), this gridded approach more explicitly identifies areas of high/low power and potential for aliasing for the entire antenna pattern.

Also, it inherently accounts for all sidelobes up to some appropriate distance from the target, instead of just the primary lobes.

Conclusion and Future Direction: The improved visualization of Mini-RF's targeting geometry has increased the quality of processed data, and has better informed target prioritization decisions. The visualization is being improved to allow for a more rapid and iterative planning process, as oftentimes an adjustment in the radar planning phase can affect flight constraints, etc. A new gridded approach to radar targeting geometry allows for better representation of the collect as a whole, rather than just the target location. We hope to additionally adjust for the effects of topography, and determine the computational limits of this approach.

References:

[1] Chin et al., 2007, Space Sci. Rev. 129(4), 391-419. [2] Nozette et al., 2010, Space Sci. Rev., 150, 285-302. [3] Patterson et al., 2013, 44th LPSC, #2380. [4] Patterson et al., 2017, Icarus, 283, 219; [5] Turner F. S. et al. (2017) PDW 3rd, Abstract #7062.

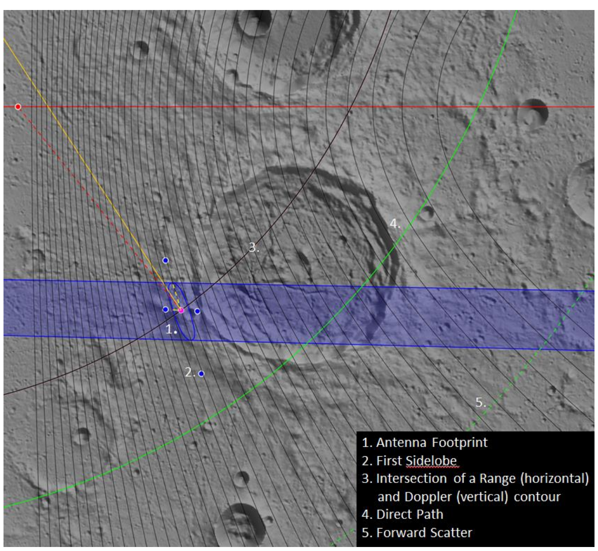

Fig. 1. Radar planning plot showing the phenomena discussed in this abstract. This demonstrates ambiguity modeled as contours, originating from the target point.

Fig. 2. An example of ghosting. Most likely caused by sidelobe aliasing along contours of ambiguity.