Disclaimer:
This document is intended to document and analyze the performance of the Open Source ADS-B Receiver (aka Stratux) Project. All data in this analysis was collected from the author's Open Source ADS-B Receiver Build. Due to variations in component selection and packaging of the Receiver project the performance of other Open Source ADS-B Receivers may differ from those of the author.

Introduction:
This analysis examines the received signal performance of various 978 MHz antennas. It starts with the most common type antenna used in a Stratux build (NooElec stock antenna) then expands to other antenna topologies. The analysis also looks at antenna performance when an antenna is used with and without a ground plane. The analysis will be expanded to include other antenna topologies as time and budget allows. A separate analysis may be performed to examine the receive performance of the 1090ES antennas with the analysis will be covered in a separate document.

Sample data:
To date the antenna topology and installation parameters for the collected data are:
1a) Stock NooElec antenna tuned for 978 MHz and placed over a metal plate,
1b) Stock NooElec antenna tuned for 978 MHz and placed over a non-conductive surface,
2a) First generation* dmurray14 “short” antenna tested with a ground plane,
2b) First generation* dmurray14 “short” antenna tested without a ground plane,
3a) Homebrew vertical dipole antenna (reference github issue 203) with a ground plane,
3b) Homebrew vertical dipole antenna tested without a ground plane,
4a) A second generation dmurray14 “short” antenna with a ground plane,
4b) A second generation dmurray14 “short” antenna tested without a ground plane,
5a) dmurray14 High Gain antenna with a ground plane,
5b) dmurray14 High Gain antenna tested without a ground plane,
6a) Digikey (Linx) ANT-916-CW-HWR-SMA-ND with a ground plane,
6a) Digikey (Linx) ANT-916-CW-HWR-SMA-ND without a ground plane
*The first generation dmurray14 “short” antennas were replaced by the current “short” antennas.

Stratux Configuration:
Stratux Build used for this evaluation:
- EdiMax Wi-Fi Dongle
- Dual NooElec 820T2 dongles (originally specified 820T2 dongles)
- Raspberry PI - Vilros Kit
- 5V DC Fan
- Ship Power via a MyGoFlight 28V to 5V USB power adaptor
- 6” MCX(M)-SMA(F) pigtails to interface to the antenna port on the SDR dongle
- Copper tape placed inside the plastic case to provide a Ground Plane for the antennas.

Reference GitHub Issue 203 for details of the Stratux build.

The Stratux was mounted on the dash of a vehicle to replicate a user placing it on the glare shield on an aircraft. Each run was conducted during a commute that passes the IXD UAT tower.

Data Collection:

The antennas were affixed to a stable Straux build and the tower signal data was recorded and analyzed. Each antenna type was attached to the Startux unit and the data was recorded while driving from a distance of approximately 15 miles east of and traveling toward the IXD UAT ground station. The starting point is behind a ridge that shields the UAT Tower from Stratux. As the vehicle is driven toward the tower it crosses over a small hill just behind the ridge. If the Stratux has enough receive sensitivity it will start receiving Tower data at the top of the first hill traveling east. The line of sight from the first hilltop to the tower location is still obscured by the ridge. Otherwise, the vehicle will have to top higher hills while traveling toward the tower to receive any tower data. The recording continued while driving away from the ground station. The intent was to simulate flying toward, over and past a UAT ground station. The logs were downloaded and analyzed. The power level is as recorded from the SDR. The SDR has approximately 35 - 40 dB dynamic range saturating at +1.4 dB while having a minimum received level of approximately -35 dB.

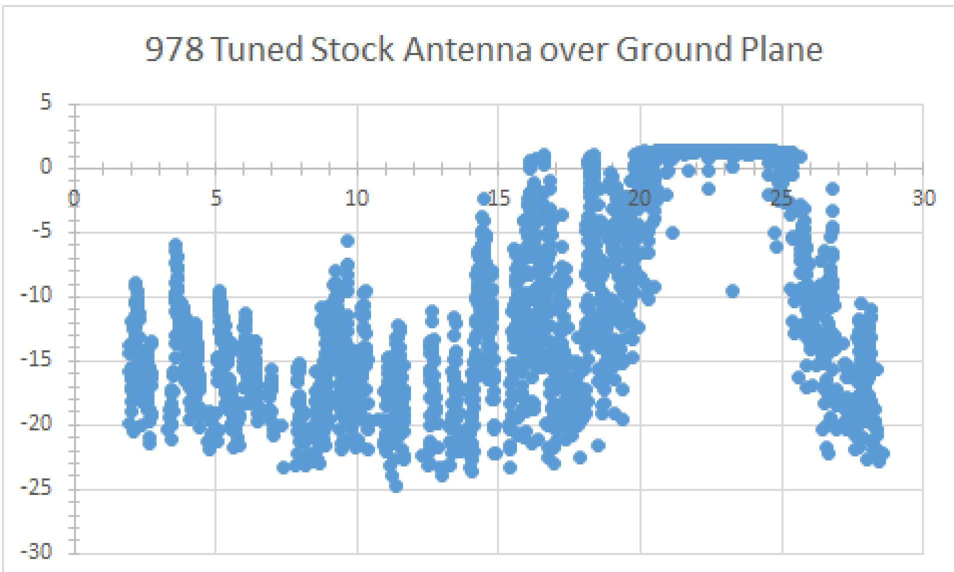
Stock NooElec Antenna

The first antenna most Stratux builders utilize is the telescopic antenna that comes with the NooElec SDR kit. This is a multi-segment nickel over copper antenna designed to mount in a magnetic base. The design intent is to magnetically attach the antenna to a ferrous metal to provide a stable mounting surface and an adequate ground plane for the antenna. For this evaluation, the author placed the stock antenna on a piece 5” x 7” galvanized flashing. This provided the minimum 978 MHz quarter wavelength ground plane for acceptable antenna performance.

A note on antenna grounding: When the antenna does not have a proper ground (or radials) it is not decoupled from the feedline and the shield of the feedline coax becomes “hot” due to the RF currents flowing on the outside shield. The currents on the shield will interact with any RF conductive surface thus detuning the antenna and reducing antenna performance.

Tuned Stock Antenna over Ground Plane:
A NooElec stock antenna was placed on a metal plate and tuned at 978 MHz for maximum received signal at a moderate range and signal strength (-20 dB) from the tower. Following tuning, the vehicle was reset to the starting point and driven toward the UAT tower. The data was recorded and analyzed.

Referring to Plot 1, the tower signal was acquired at the 1:30 minute mark as the vehicle crossed the first hill behind the ridge. At approximately the 3:00 minute mark the vehicle entered a valley and the signal was momentarily lost. This repeated at approximately the 7:30 minute mark and 12:00 minute mark while traveling toward the tower. The signal peaks at approximately +1.4 dB and occurs at the 16:30 mark, the 18:00 mark and through the 19:30 - 25:30 minute marks. The minimum signal strength observed was -25 dB for a received range of 26.4 dB.



Plot 1

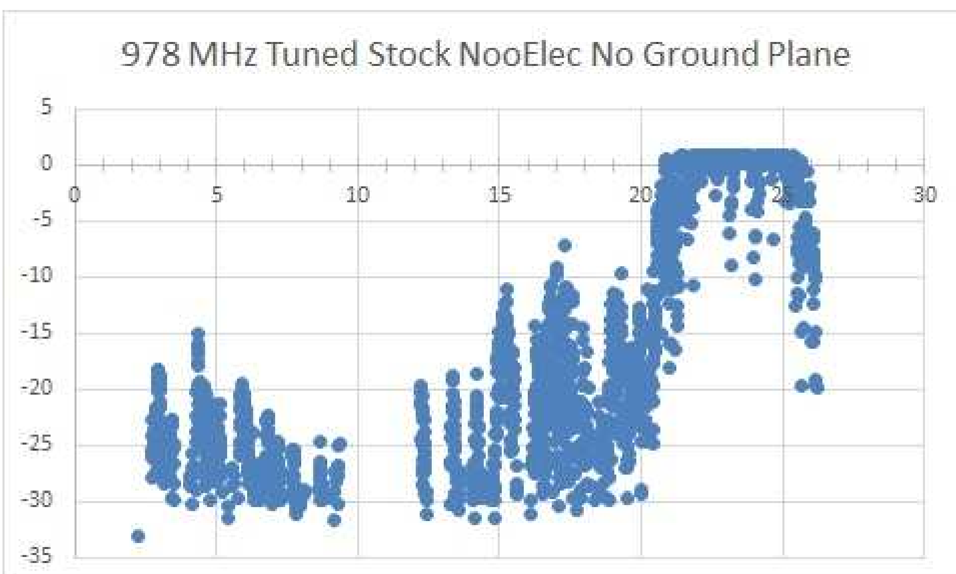
Tuned Stock Antenna over a non-conductive surface

The tuned Stock antenna was removed from the metal plate and placed over a non-conductive surface (vehicle dash) and the vehicle was repositioned to the original starting point.

Note: There was an issue where Stratux dropped out part way through the test creating a gap in the recorded data. The plot is missing approximately three minutes of data where Stratux dropped out, but it doesn't impact the overall analysis. The dropout issue was corrected with a subsequent software issue.

The first strong tower reception occurred at approximately 3:00 minutes and correlates to the second hilltop in Plot one. This hilltop is approximately a mile closer to the tower. Gaps in tower reception occurred at approximately the 4:00, 5:00, 7:30. 8:00, 13:00, 14:00, and 16:00 minute marks. Some of these gaps were significant enough to cause a decrease on the UAT message rate.

When looking at the moderate received signal strength (-10 dB to -20 dB) the Stock antenna without a ground plane shows approximately a -10 dB decrease in received signal strength compared to the antenna mounted on a metal surface. This equates to approximately a 30% to 50% reduction in received tower distance.



Plot 2

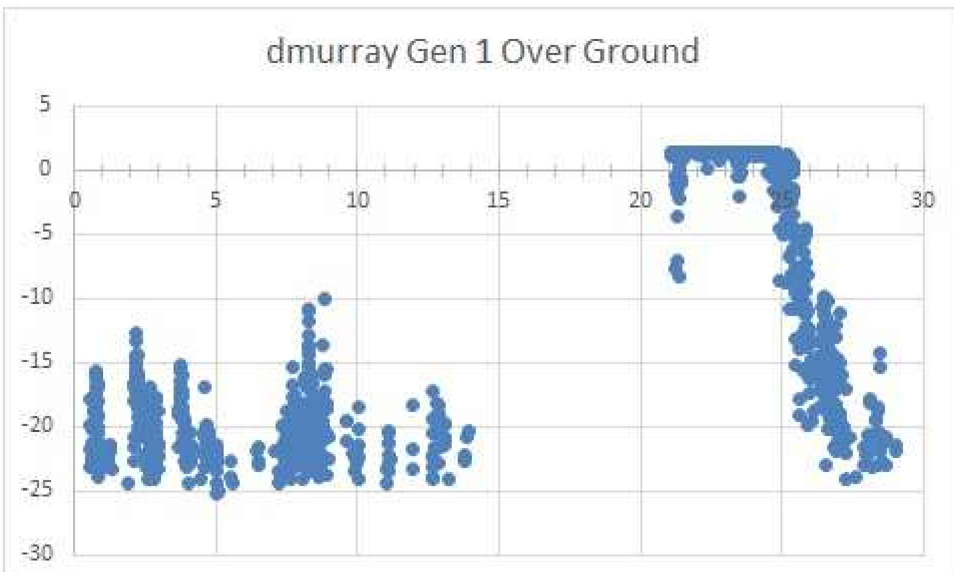
First Generation dmurray14 Antenna (short antenna)

The second antenna choice for a number of Stratux builders is the dmurray14 antenna. Aside from a QC issue with a later production run, a number of users have documented their experiences with the antenna. The antenna used for this analysis was from the original production run.

dmurray14 Antenna with ground

Note: Due to a Stratux issue, the middle portion of the data set is missing.

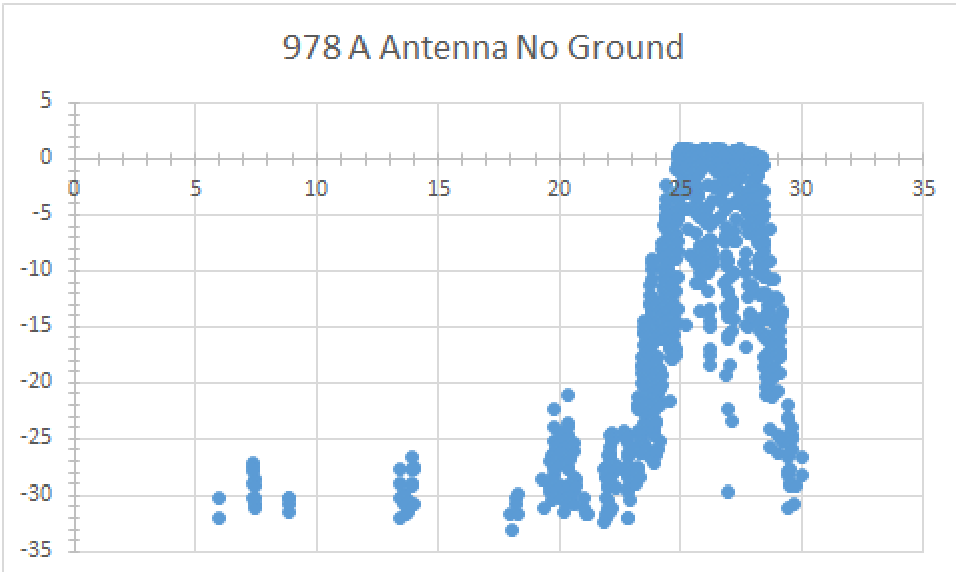
The performance of this antenna is similar to the performance of the stock NooElec antenna without the ground plane (Plot 2).



Plot 3

dmurray14 Antenna without ground

Comparing Plot 4 to Plot 3 above there is a much as a 70% reduction in the number of received tower hits with approximately a 15 dB reduction in received signal strength. This is about a 40% reduction in received UAT tower range. Tower reception started about 5 minutes / 5 miles later than with the previous “with ground” configuration. In this configuration, Stratux does not sustain a maximum received signal level when in close proximity of the tower as shown by the “fill” under the signal peak.



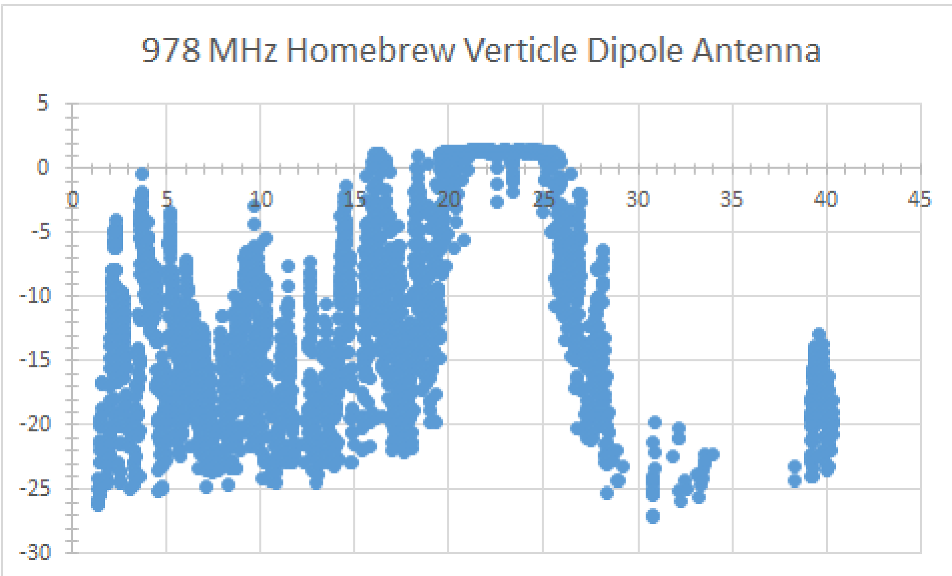
Plot 4

978 Homebrew Antenna - Vertical Dipole antenna topology

978 Homebrew Antenna with ground

The author designed and built a homebrew antenna for the Stratux build. Additional information about this antenna is documents on Github in Issue 203.

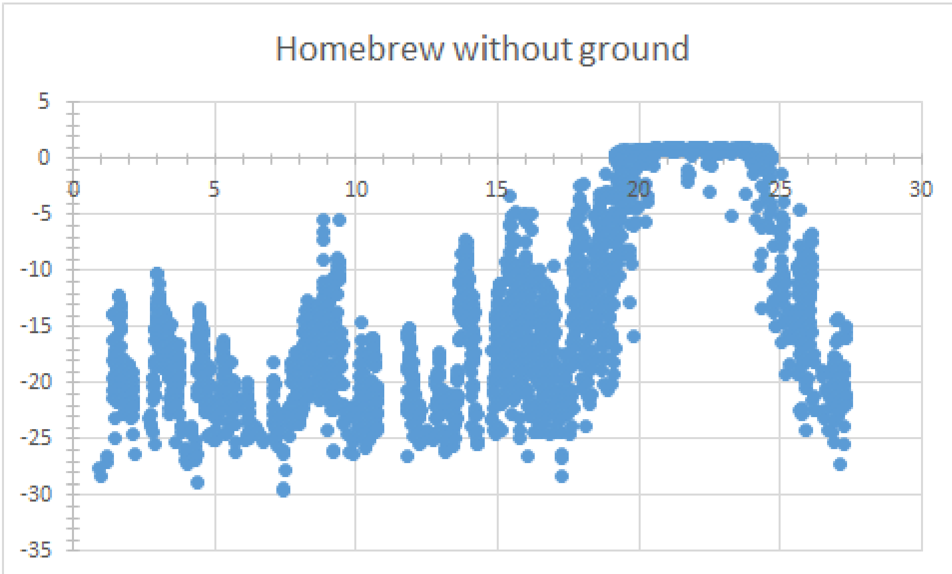
This antenna consistently acquires the tower signal at the hilltop behind the ridge. The overall signal strength of this antenna (Plot 5) is approximately 5 dB to 8 dB stronger than the Stock antenna over a ground plane (Plot 1). It also consistently keeps a “lock” on the tower signal when traversing the valleys traveling toward the tower as illustrated by the plot fill between the one and 16 minute marks.



Plot 5

978 Homebrew Antenna with without ground

The Homebrew antenna without ground (Plot 6) showed to have about 10 dB less performance that when installed with a ground (Plot 5). Example: The peak at the plot 5 four minute mark is 10 dB greater than the peak at the plot 6 three minute mark.



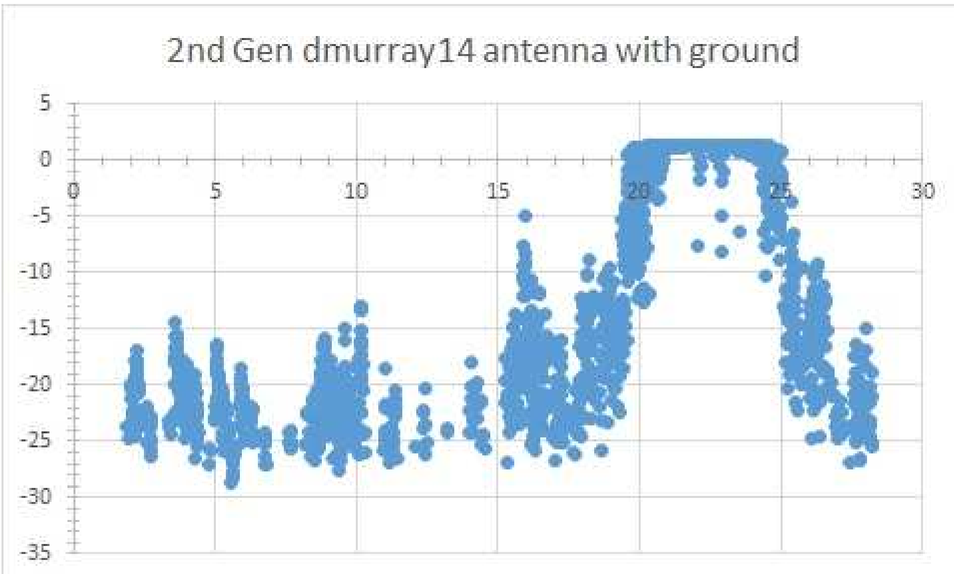
Plot 6

Second Generation dmurray14 Antenna (short antenna)

Second Generation dmurray14 Antenna with ground

After the author posted a series of documents analyzing the performance of his Stratux build, he was contacted by dmurray14 to test and analyze the performance of a second generation of the antenna. This is a summary of that activity.

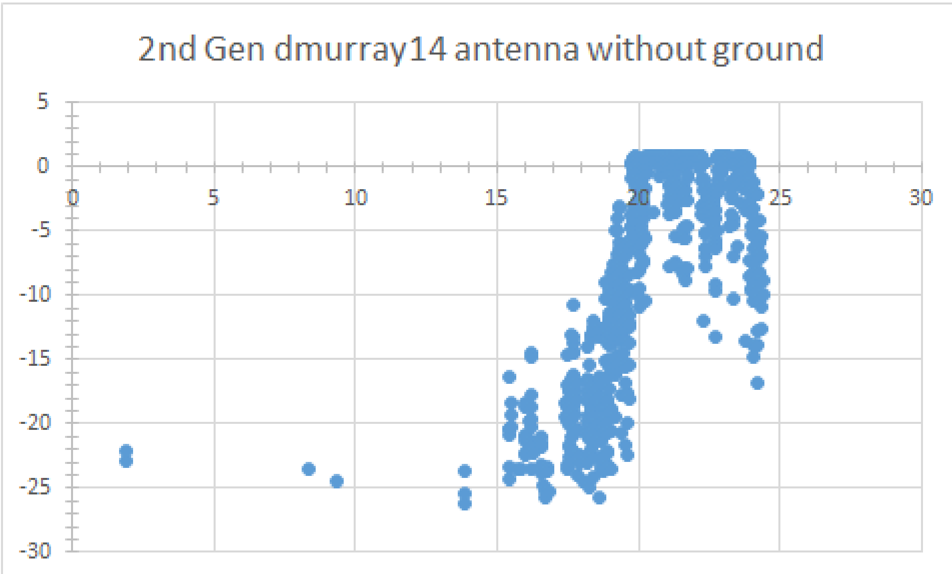
As with the first generation antenna, the Gen2 antenna was mounted to a ground plane. In this configuration the antenna showed improved receive performance (Plot 7) over the first generation antenna (Plot 3). It maintained consistent signal reception while traversing through the valleys and there was no observed decrease in the UAT message rate during those periods. The second generation shows a 2 dB to 3 dB improvement of received signal strength over the first generation of the antenna.



Plot 7

Second Generation dmurray14 Antenna without ground

Plot 8 is the tower signal plot of the 2nd Gen antenna without a ground plane. There were very few tower hits while driving toward the UAT tower. This is shown by the sparse data plots between the one and fifteen minute marks. The antenna had fair performance when in close proximity of the UAT tower.



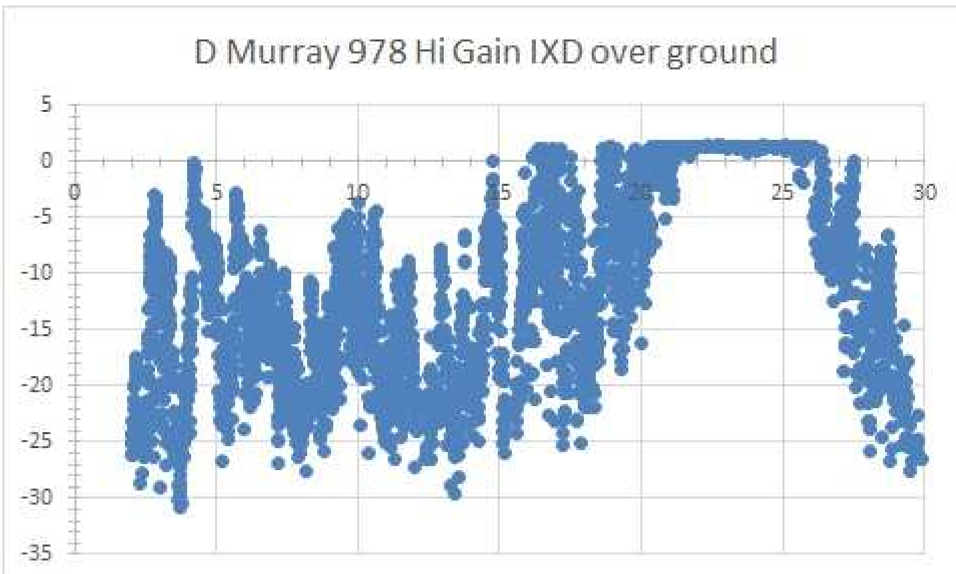
Plot 8

dmurray14 High Gain Antenna

dmurray14 High Gain Antenna with ground

In conjunction with the Gen2 testing, the author was also asked to evaluate a high gain version of the 978 UAT antenna. This is a summary of the evaluation.

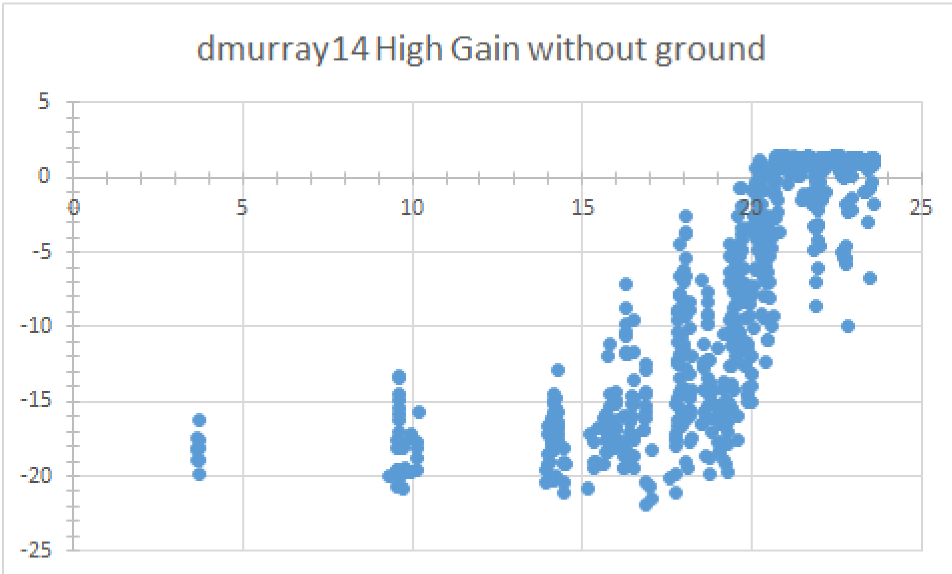
The “High Gain” antenna showed performance comparable to the author’s homebrew vertical dipole (Plot 5 v. Plot 9). When comparing the signal peaks of Plot 9 to Plot 1, the “High Gain” antenna shows approximately a 5 dB reception improvement over the NooElec Stock antenna mounted over a ground plane (Plot 1 v. Plot 9).



Plot 9

dmurray14 High Gain Antenna without ground

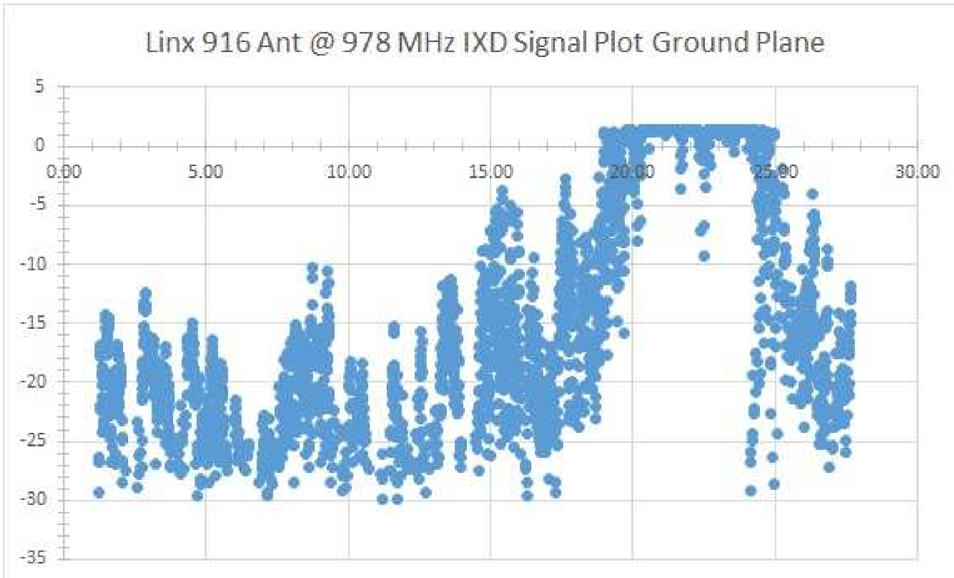
Due to a data corruption issue, the full data set wasn't recovered from the log. However, when compared to plot 9 the 15 to 24 minute dataset of plot 10 shows the signal reception is degraded when no ground plane is utilized.



Plot 10

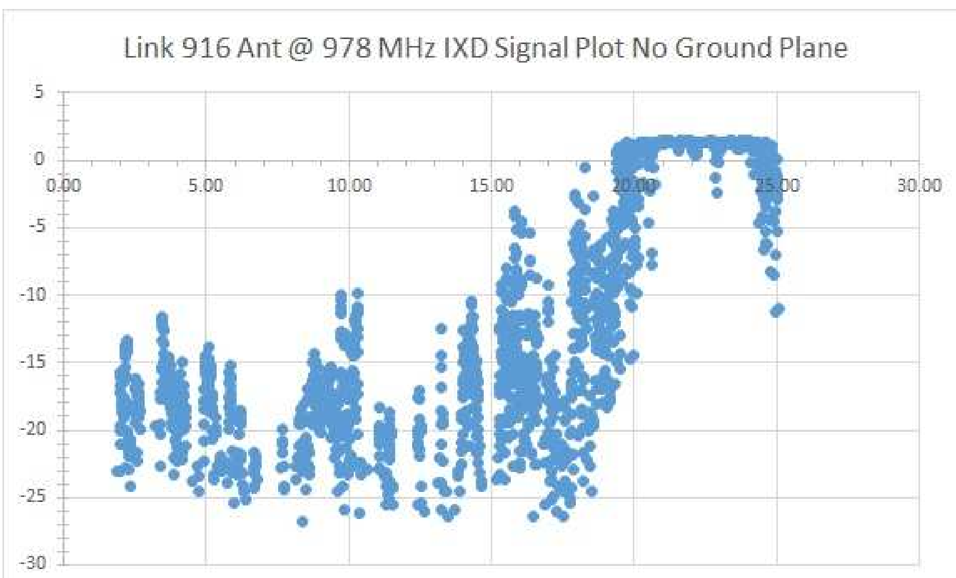
Digikey (Linx Technology) ANT-916-XXX Antenna
(Used at 978 MHz)

Digikey (Linx) ANT-916-XXX Antenna with ground



Plot 11

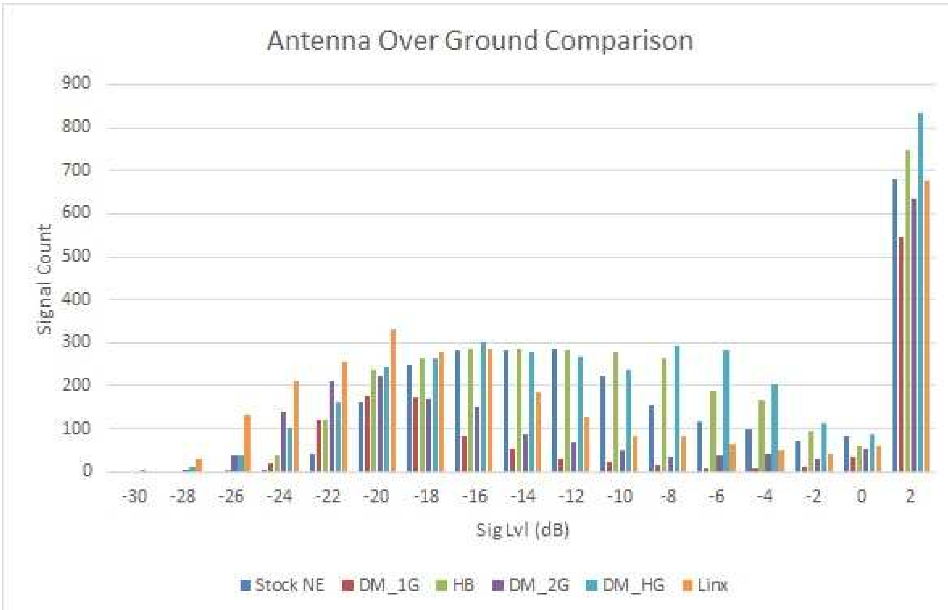
Digikey (Linx) ANT-916-XXX Antenna without ground



Plot 12

Histogram Comparison

Plot 13 compares and summarizes the signal level of all tested antennas installed over a ground plane.



Plot 13