Preliminary Results from the AFRL-NASA W/V-Band Terrestrial Link Experiment in Albuquerque, NM

Wave Propagation in Terrestrial, Oceanic and Atmospheric Environments

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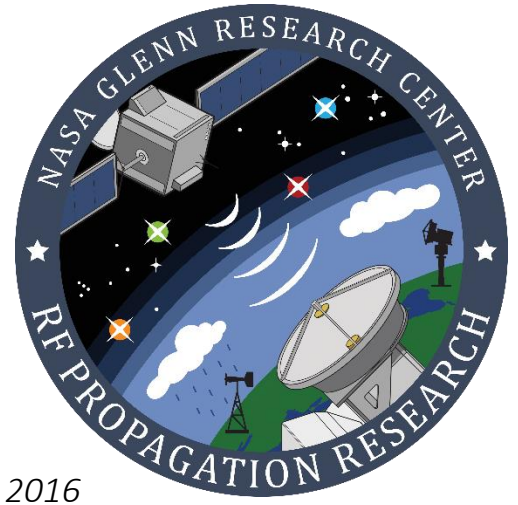
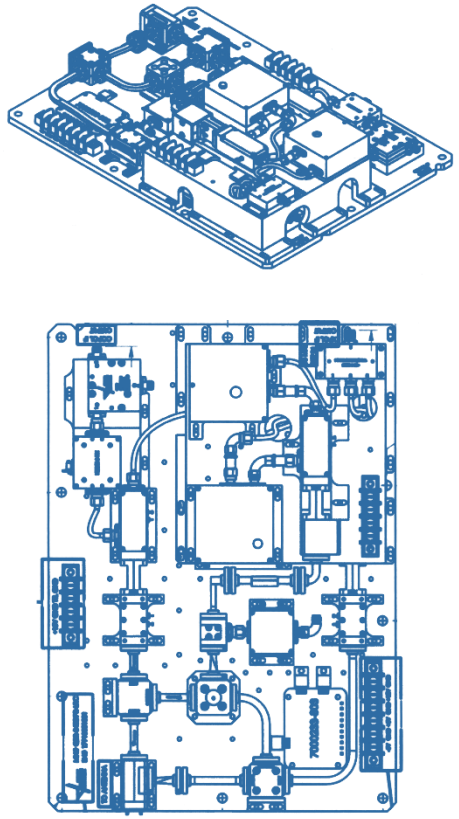


2016 IEEE International Symposium on Antennas and Propagation • Fajardo, Puerto Rico • June 29th, 2016

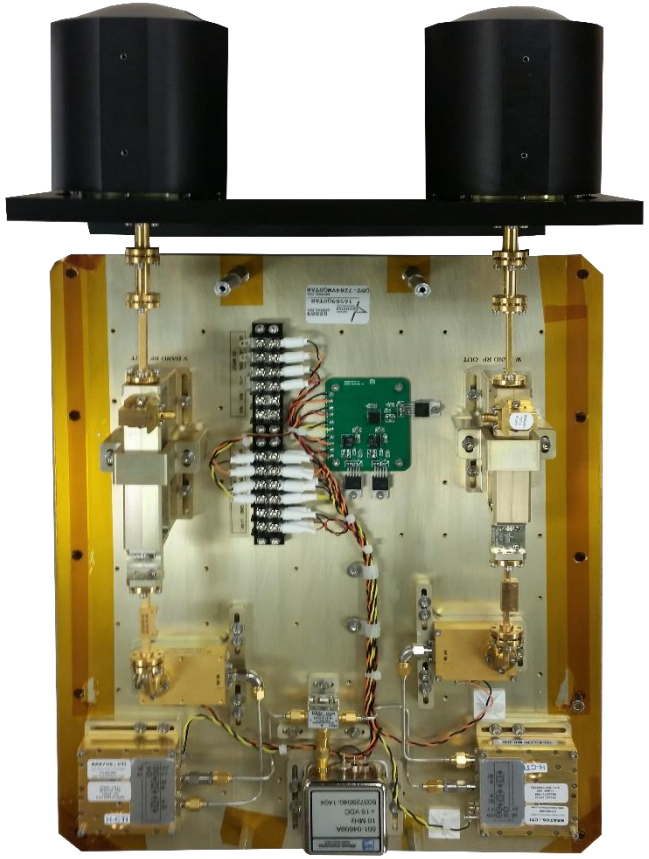
Presentation Overview



Wireframe schematic of the WTLE receiver front end electronics.

1. Motivation & Experiment Goals
2. Site of Study
3. Receiver Site (COSMIAC)
4. Transmitter Site (Sandia Crest)
5. Instrumentation
6. Preliminary Results
7. Solar Influence
8. Concluding Remarks

Motivation & Goals

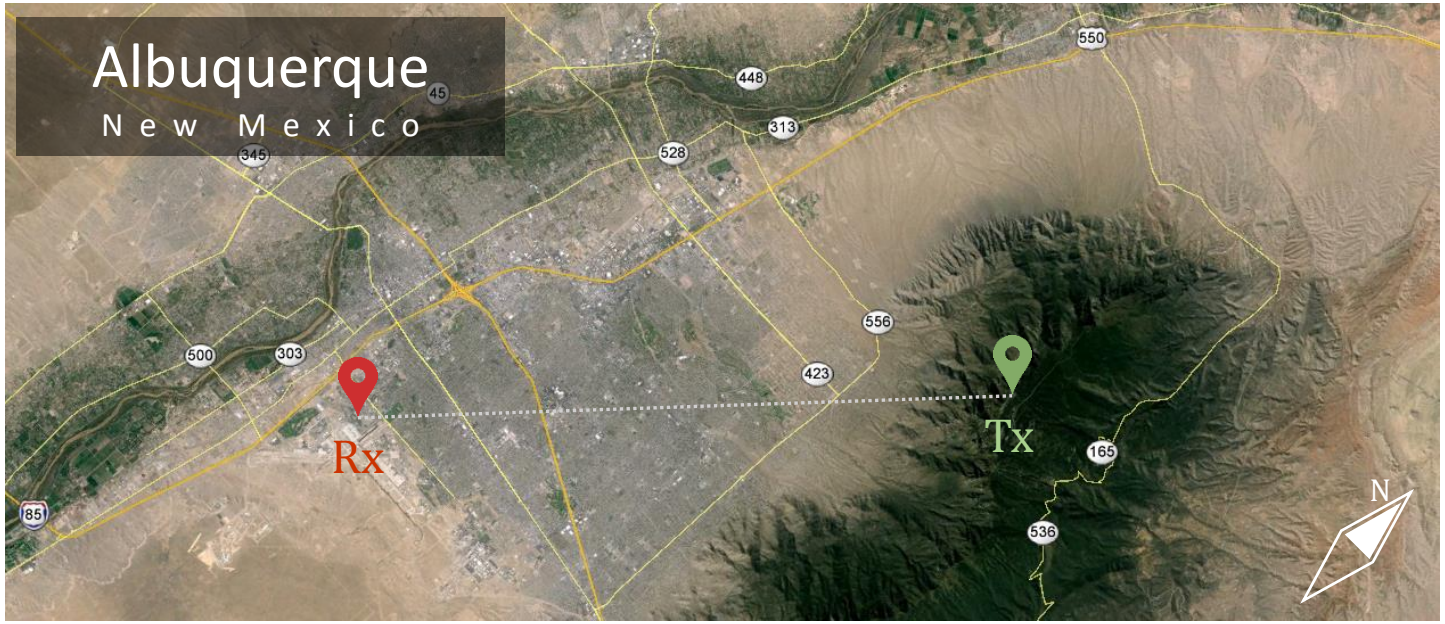


WTLE transmitter front end electronics and lens antennas.

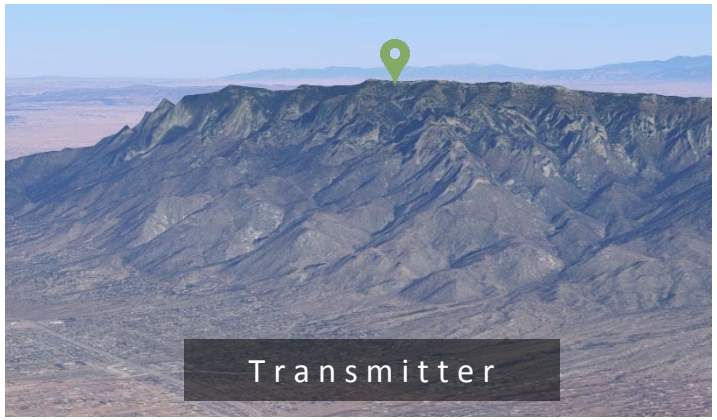
Experiment Motivation & Goals

- To **assess the impact** of atmospheric effects on links operating in the V and W-band (rain attenuation, scintillation, depolarization, etc.).
- To **develop physical models** to improve predictions of atmospheric attenuation within the V/W-band.
- To provide a **testbed** for RF propagation measurement instruments & techniques.
- To assess **optical link** performance with a side-by-side link in tandem with the existing RF link.

Site of Study



COSMIAC (University of New Mexico)
(Photo: Google Earth)



Sandia Crest
(Photo: Google Earth)

Receiver	
Site	UNM / COSMIAC (Roof)
Latitude	35.054031° N
Longitude	106.619443° W
Altitude	1.596 km
Installation Date	September 2015

Transmitter	
Site	Sandia Crest
Latitude	35.215128° N
Longitude	106.451245° W
Altitude	3.239 km
Beacon Freqs.	72 GHz 84 GHz
Installation Date	September 2015

Path	
Azimuth	40.444°
Elevation	3.984°
Path Length	23.55 km

Receiver Site (COSMIAC)

Transmitter Site (Sandia Crest)

Instrumentation

Beacon Receivers

Antenna Gain	45.6 dBi (V / W-band)
Dynamic Range	70 dB (V) /68 dB (W)
Co/Cross-Polarization Isolation	13 dB (V) / 20 dB (W)
Polarization	LHCP
Sampling Period	0.1 sec (10 Hz)

Weather Instrumentation

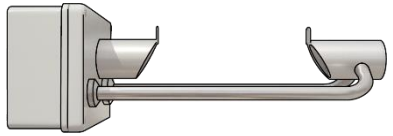
Anemometer:
Young 05178A

Temperature/Humidity Sensor:
Young 41382VC

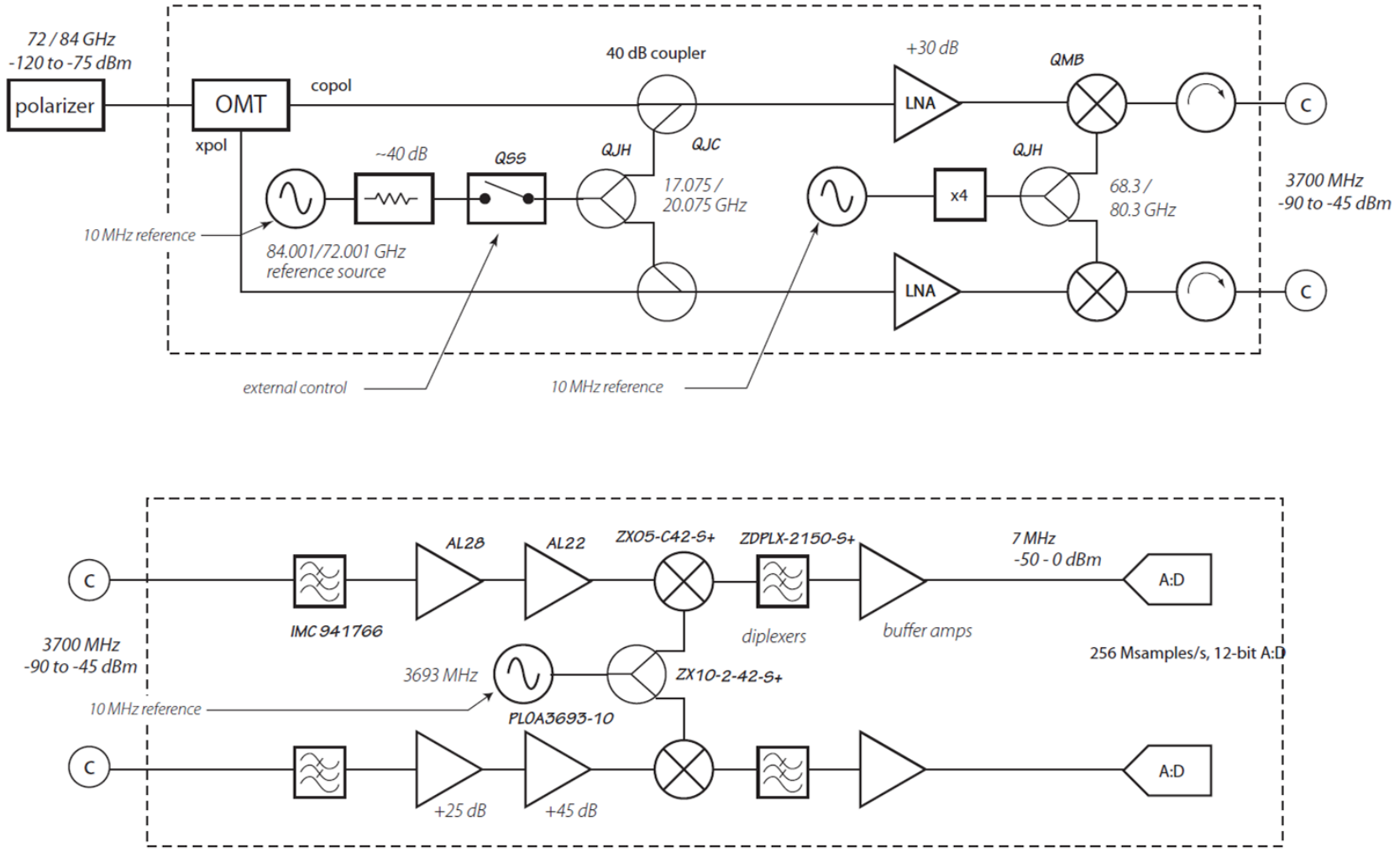
Pressure Sensor:
Young BPV3000

Tipping Bucket:
Young 52203

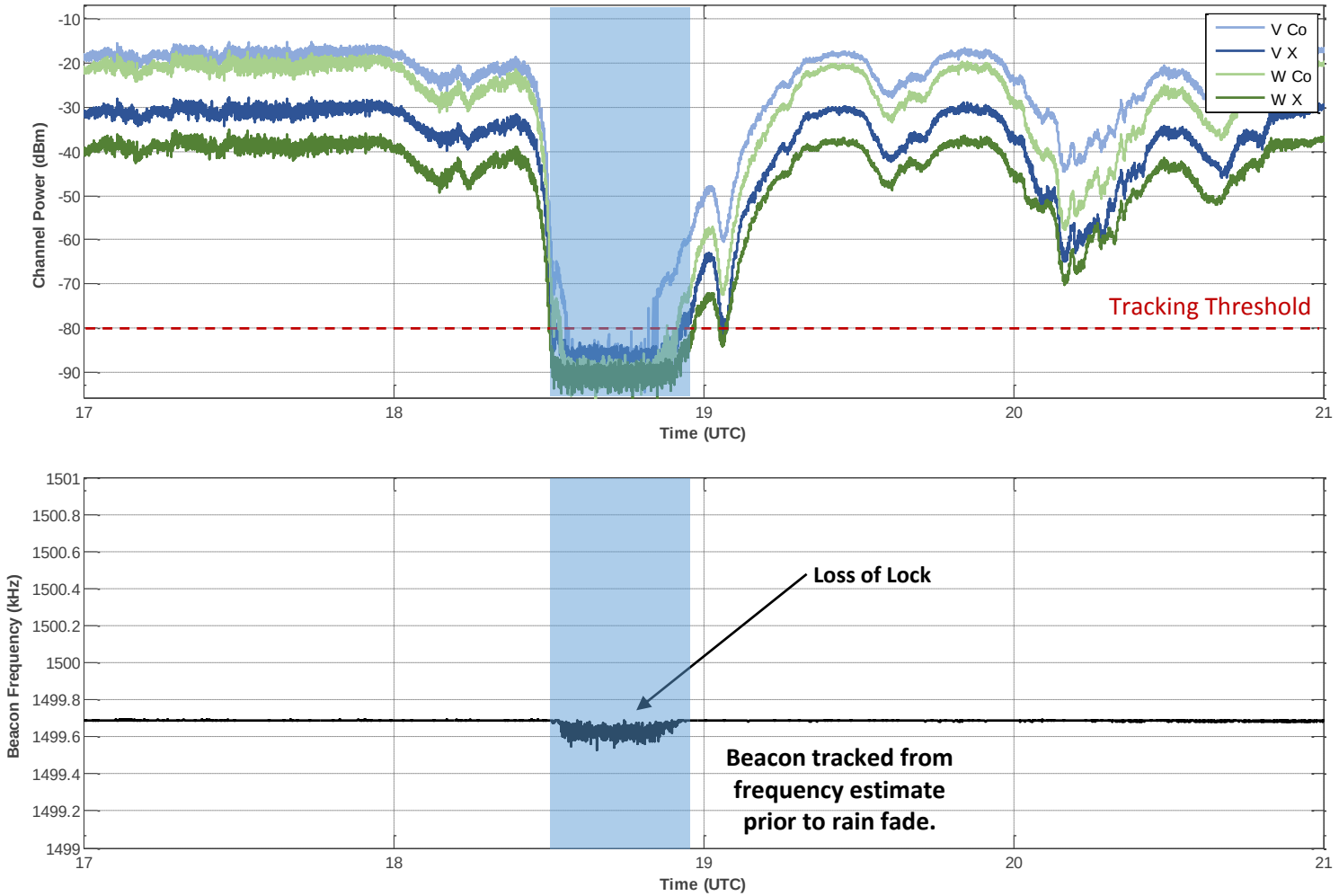
Laser Disdrometer
Thies Clima 5.4110



Block Diagram



System Performance

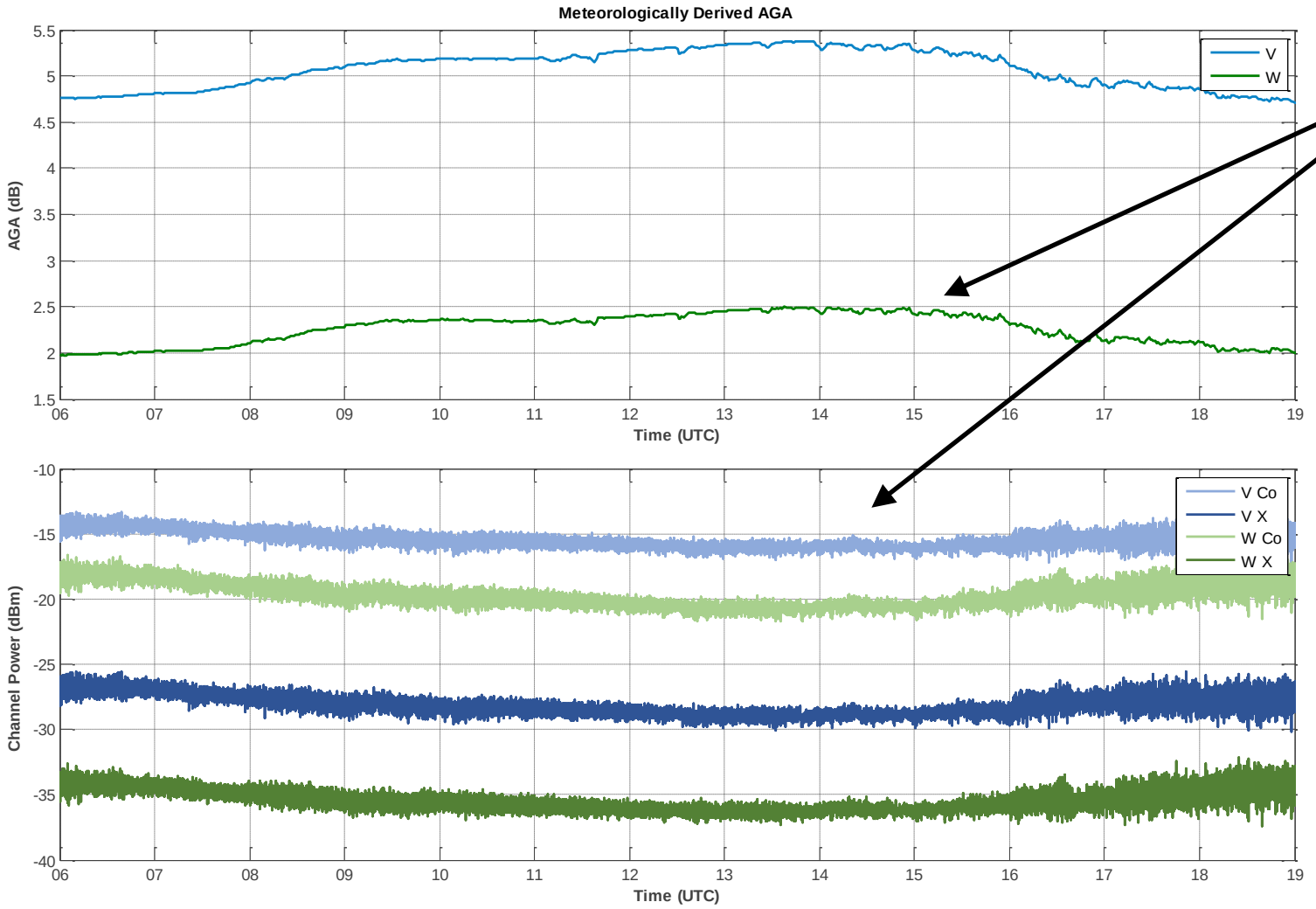


Under normal operating conditions, the V and W-band receivers track their respective beacon signals using a modified Quinn-Fernandes frequency estimation algorithm. The cross-polarization signal is tracked from the current co-polarization frequency

When attenuation approaches the noise floor (below a given power threshold), the frequency estimate is replaced by an average of the frequency estimate prior to the fade. This allows for a slight improvement in dynamic range during the beginning and end of deep fades.

Signal lock is immediately regained when the signal reappears above the noise floor.

Clear Sky Day (2015-09-30)



Diurnal variations in atmospheric gaseous absorption (AGA) observed in timeseries attenuation on clear-sky days.

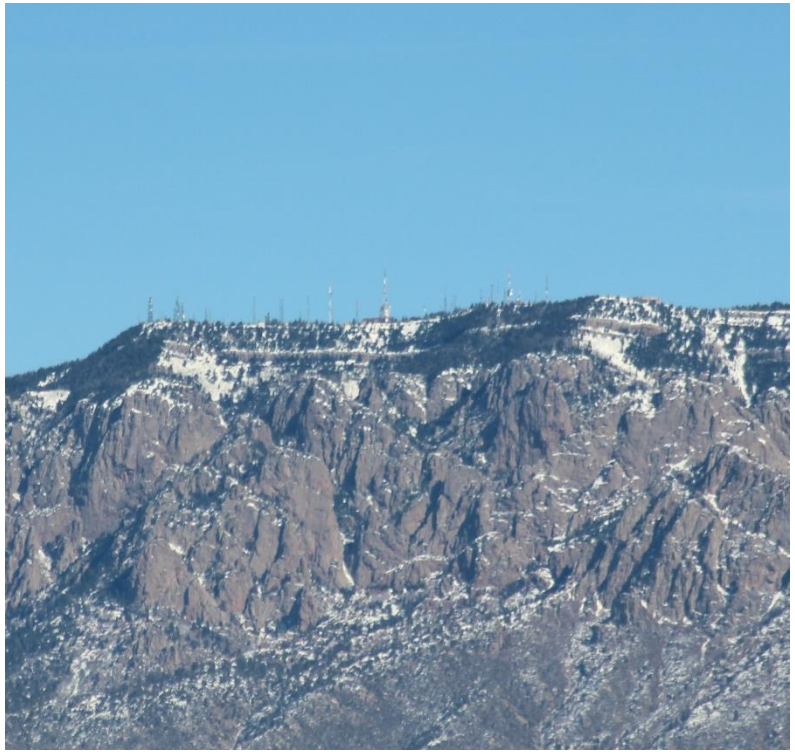
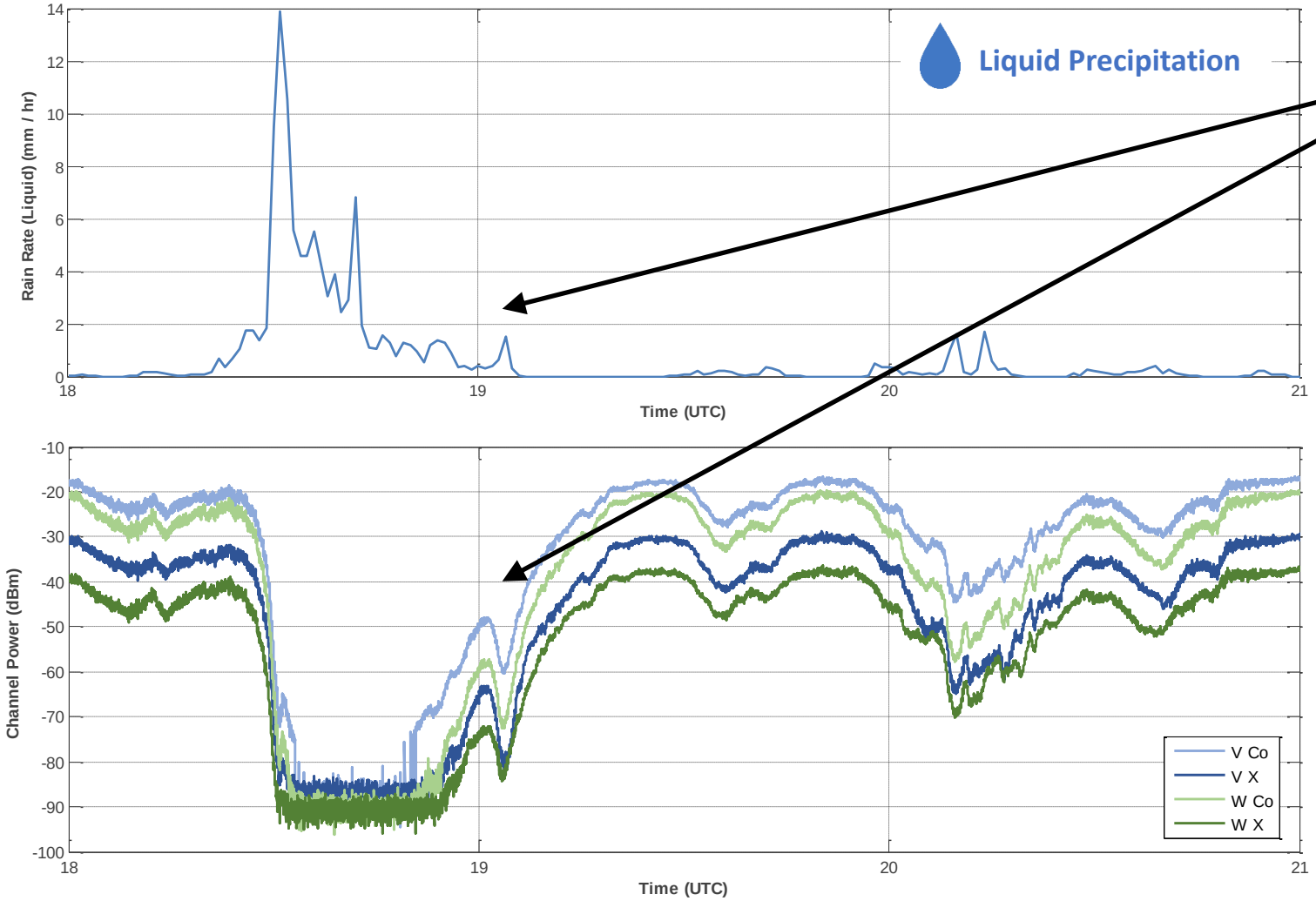


Photo Credit: NASA

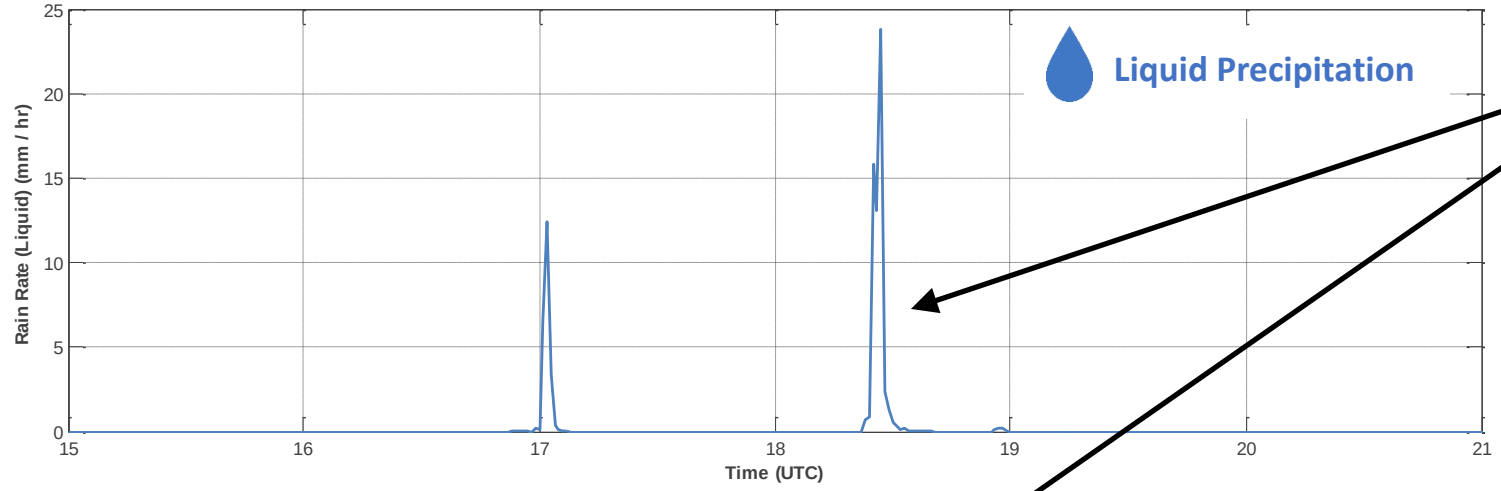
Deep Rain Fade (2015-11-04)

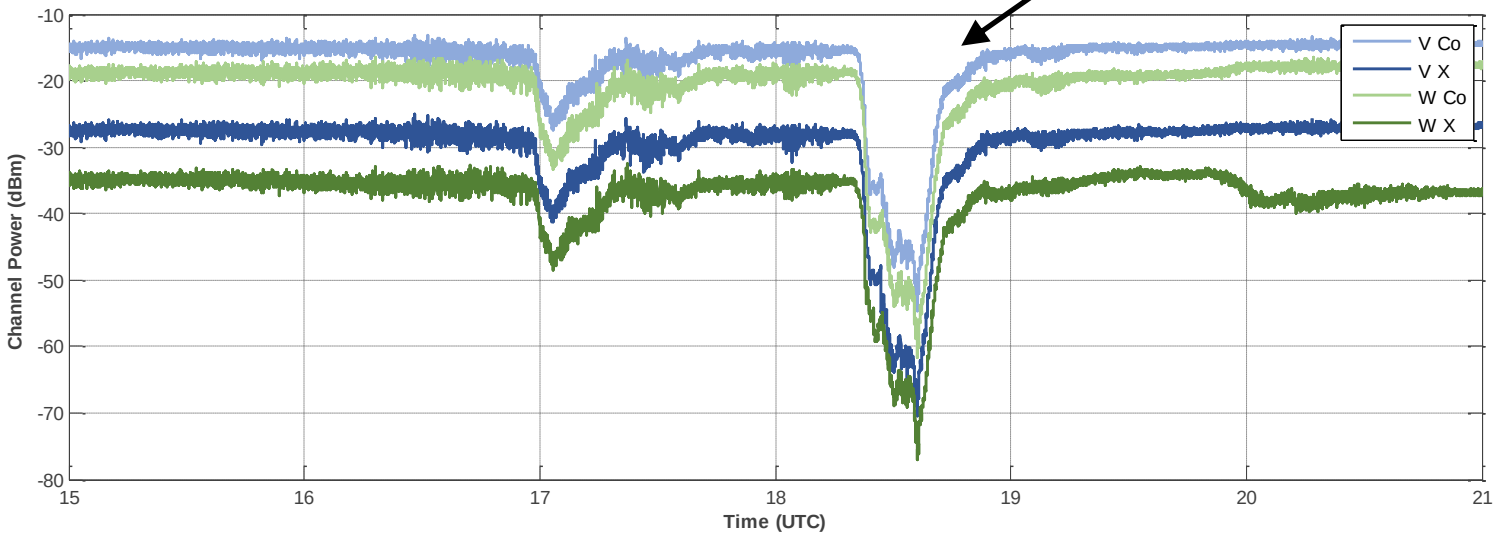


Strong rain event exceeds dynamic range of receiver on all channels.

Photo Credit: Albuquerque Journal

Rain on Path (2015-10-03)

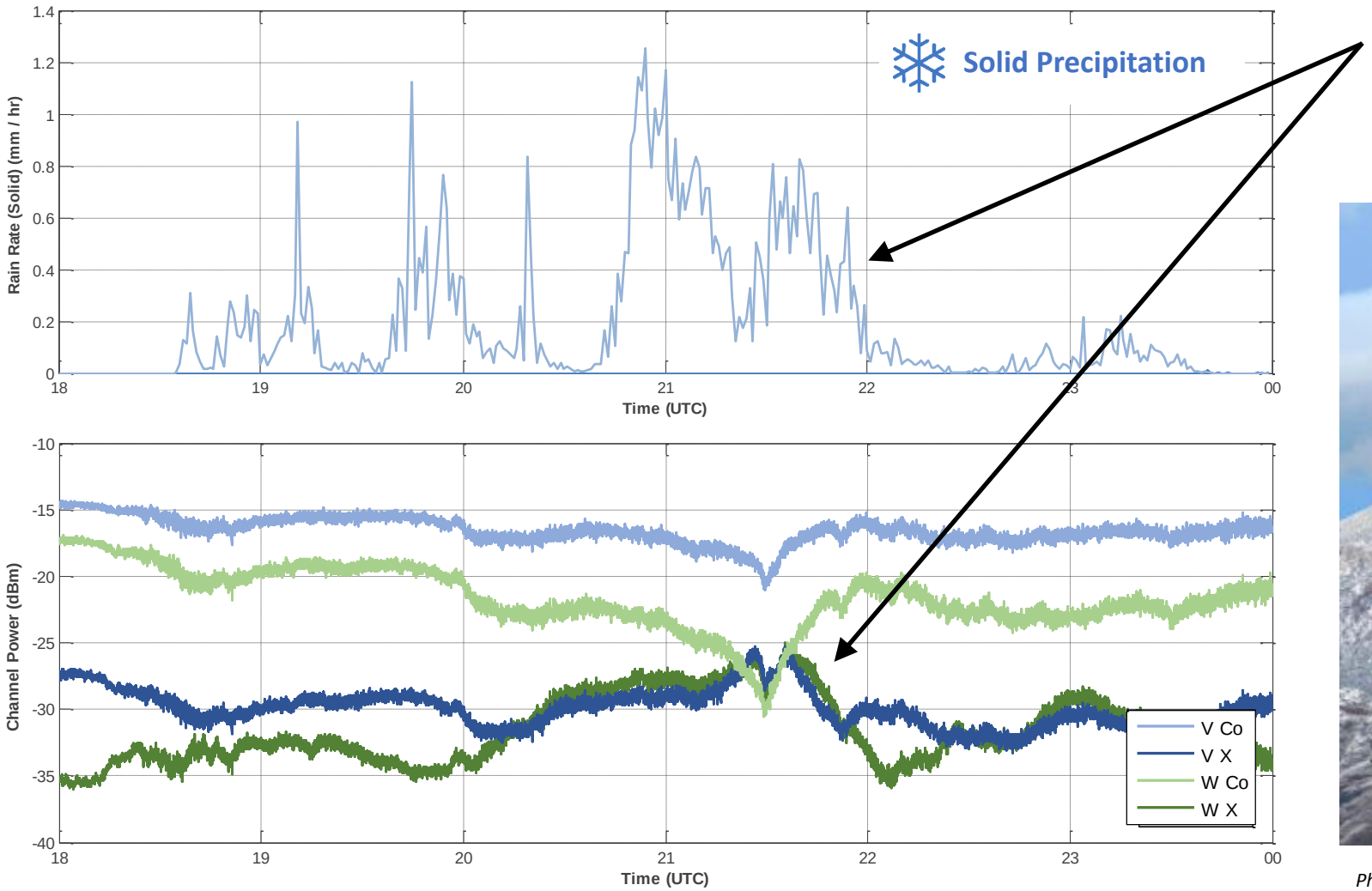




Rain at receiver subsides while rain fade continues, indicating continued rain along the path.

Photo Credit: NOAA

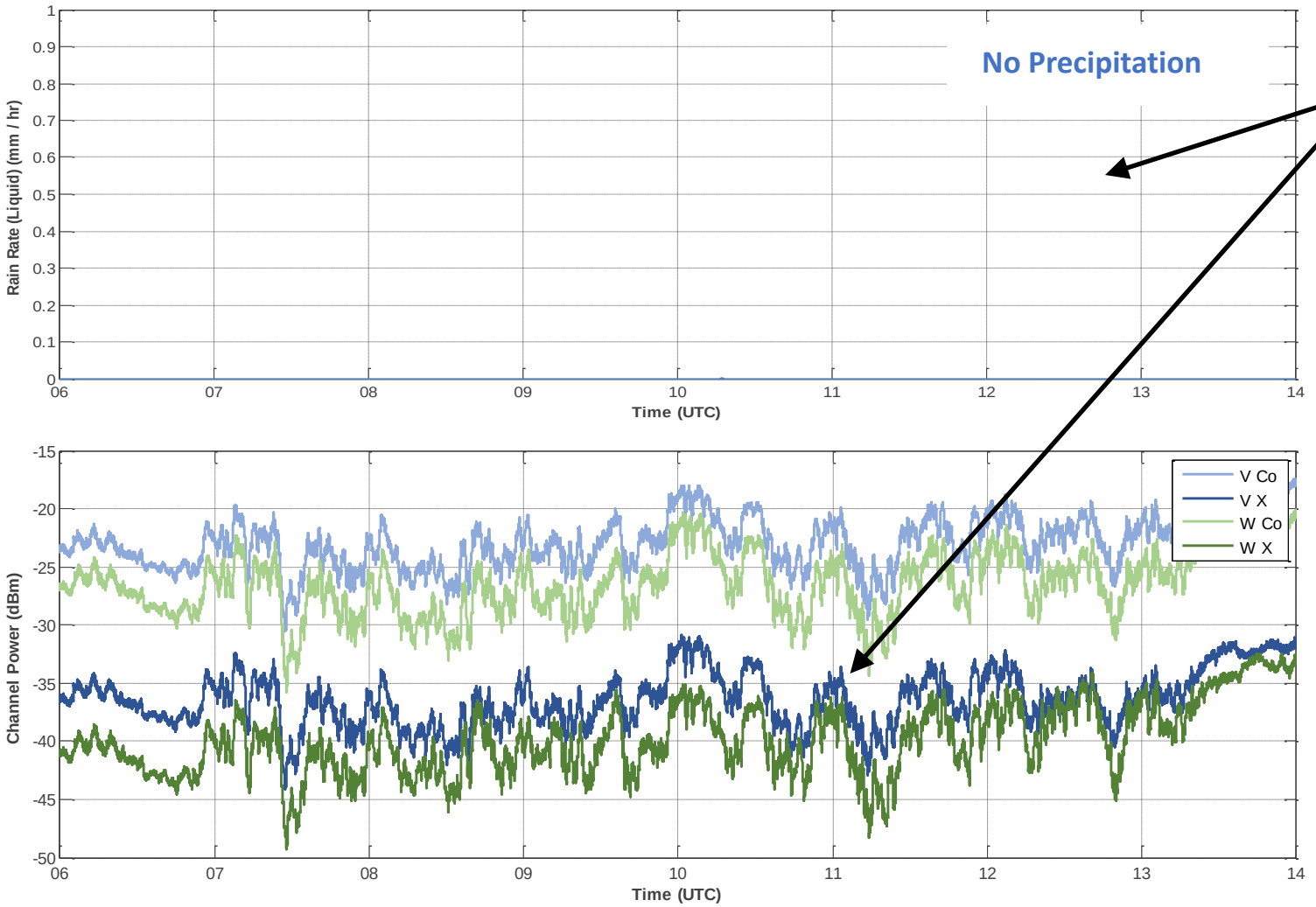
Snow / Depolarization (2015-12-26)



Strong depolarizing effects observed on both V and W-band channels during solid precipitation (snow) event.

Photo Credit: Albuquerque Journal

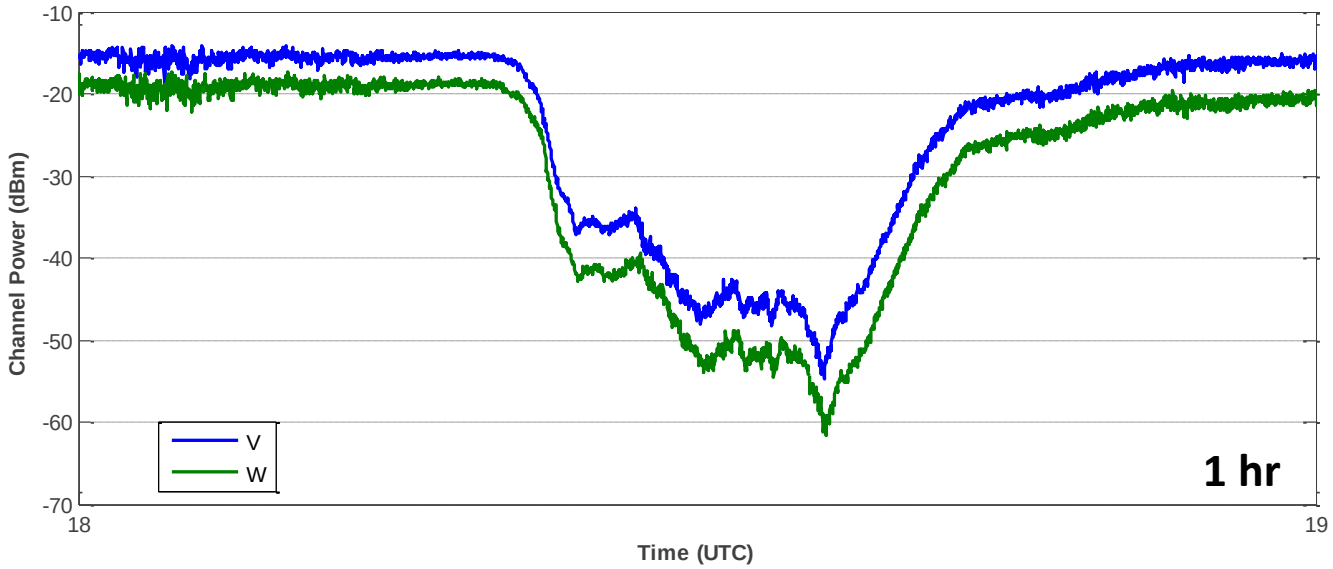
Cloud Event (2016-01-09)

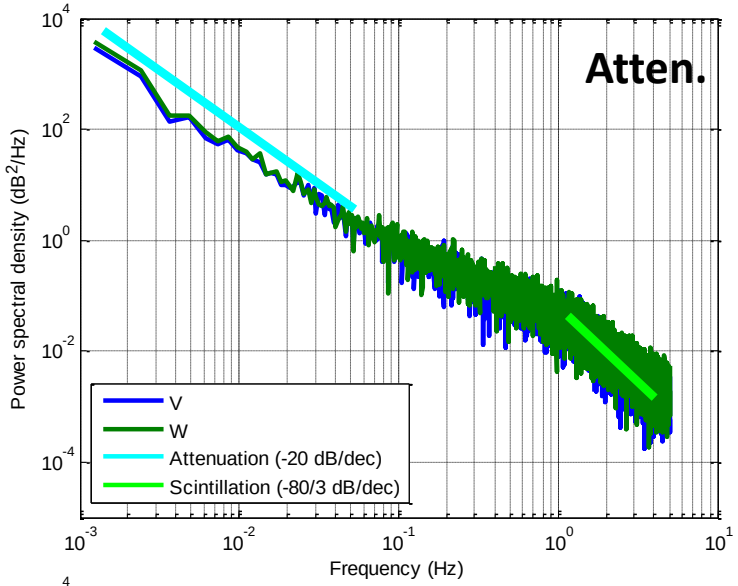


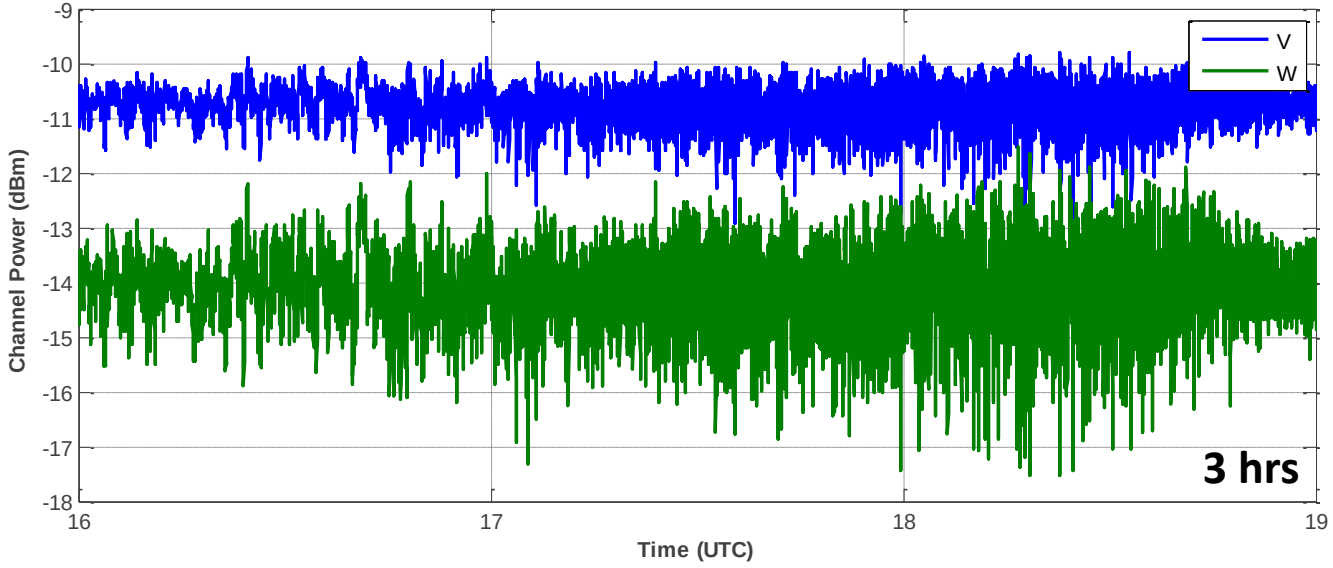
Strong fluctuations on both V and W-band channels with no precipitation while clouds obscure the peak of Sandia Crest.

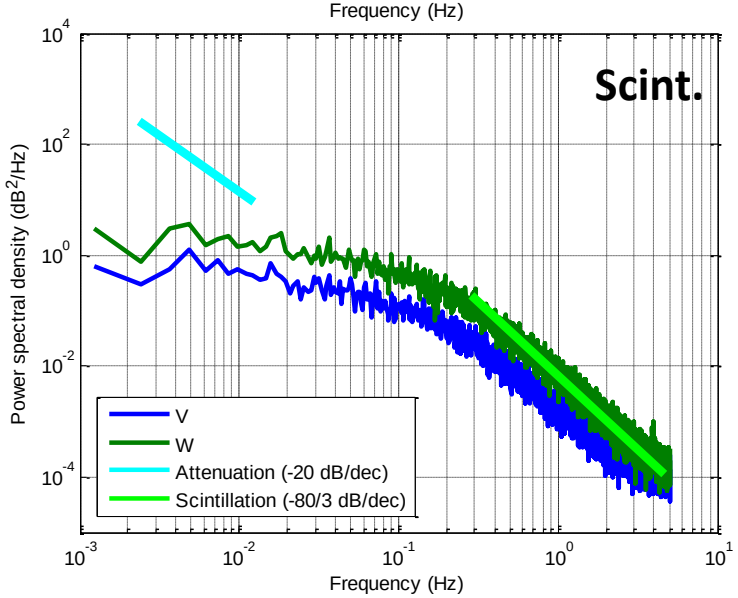
Photo Credit: NASA

Measurement Spectral Density

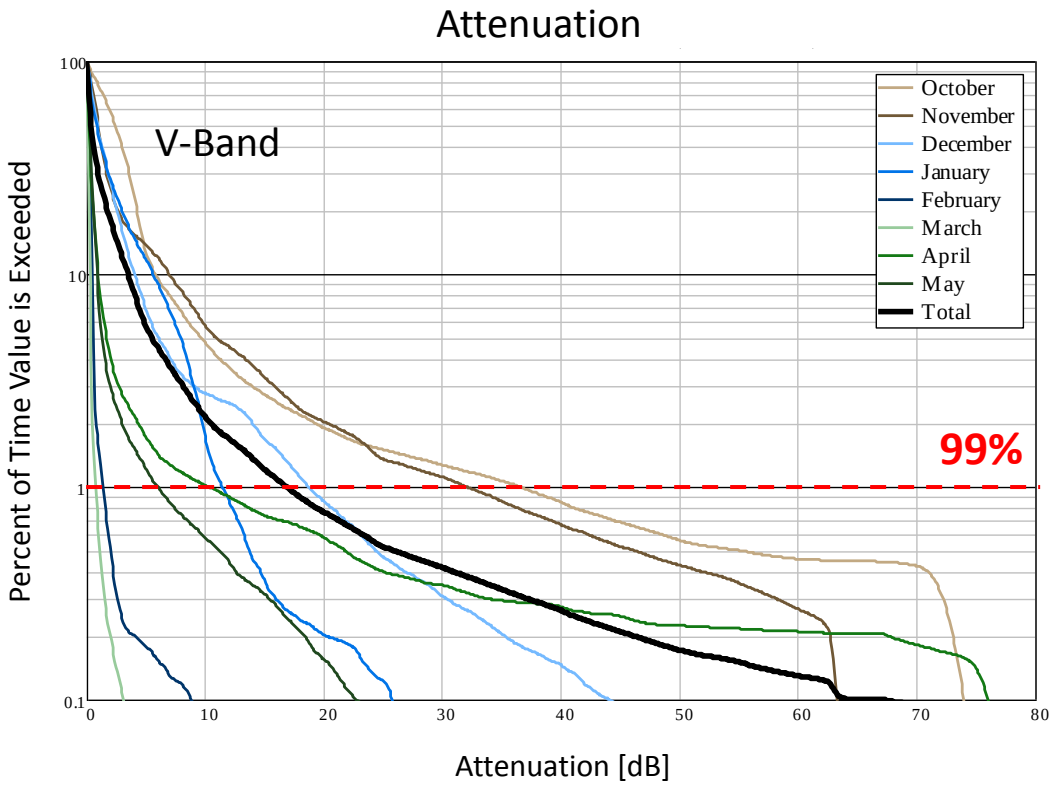


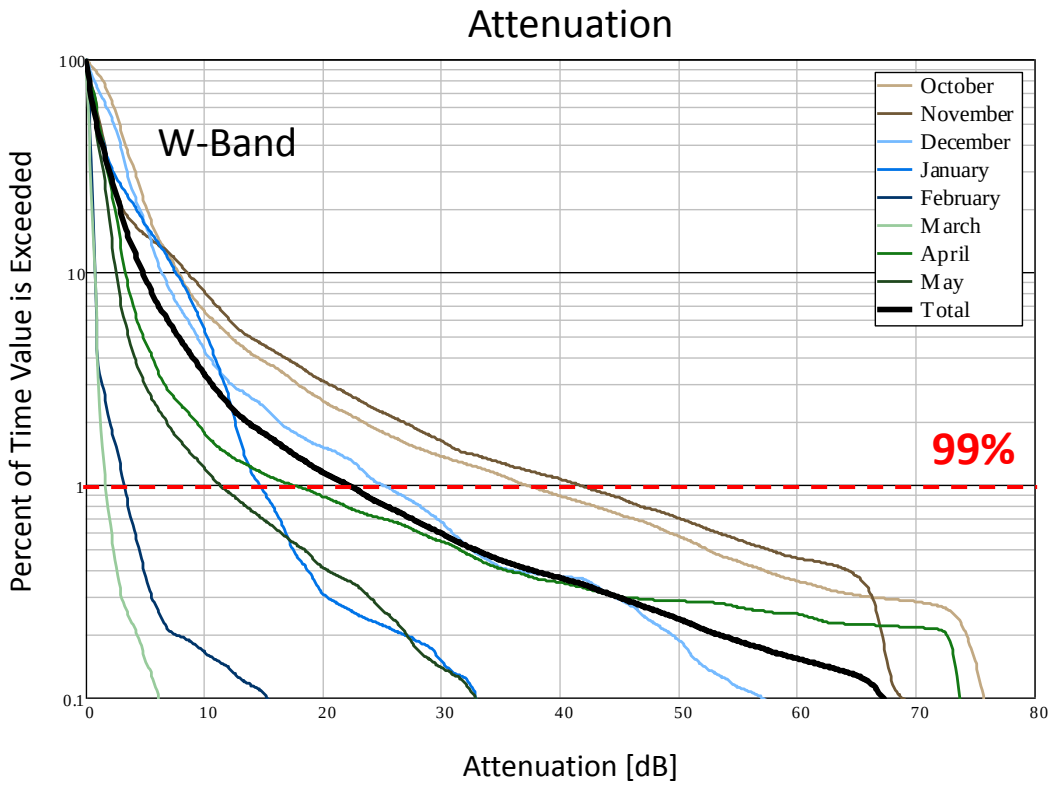






Attenuation Statistics





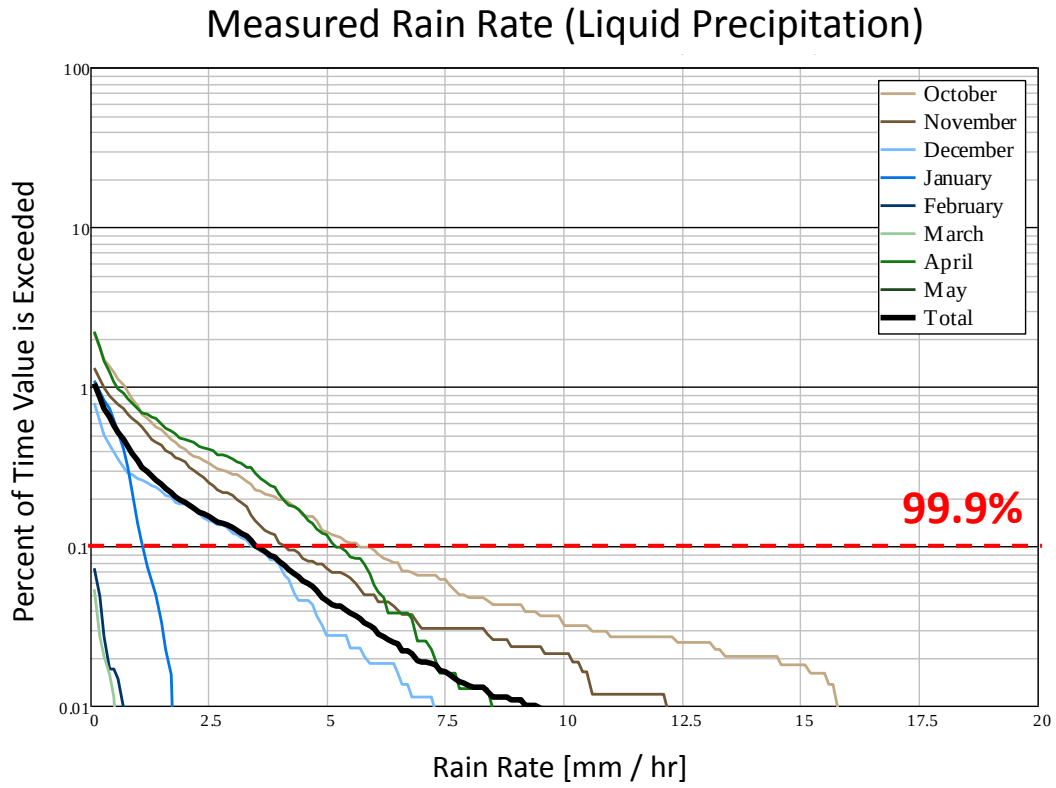
99% Attenuation
(Exceeded 1% of the Time)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Total
V	36.533 dB	31.983 dB	18.722 dB	11.457 dB	1.379 dB	0.763 dB	10.247 dB	5.971 dB	16.845 dB
W	36.967 dB	41.500 dB	24.953 dB	14.614 dB	3.249 dB	1.686 dB	17.278 dB	11.264 dB	22.065 dB

* Worst Month
* Best Month

Large month-to-month variability, up to 35.8 dB (V) and 39.8 dB (W) between the best and worst months.

Rain Rate Statistics



In total, rain was observed 1.05% of the time over the 7 month period (approx. 61.48 hours).

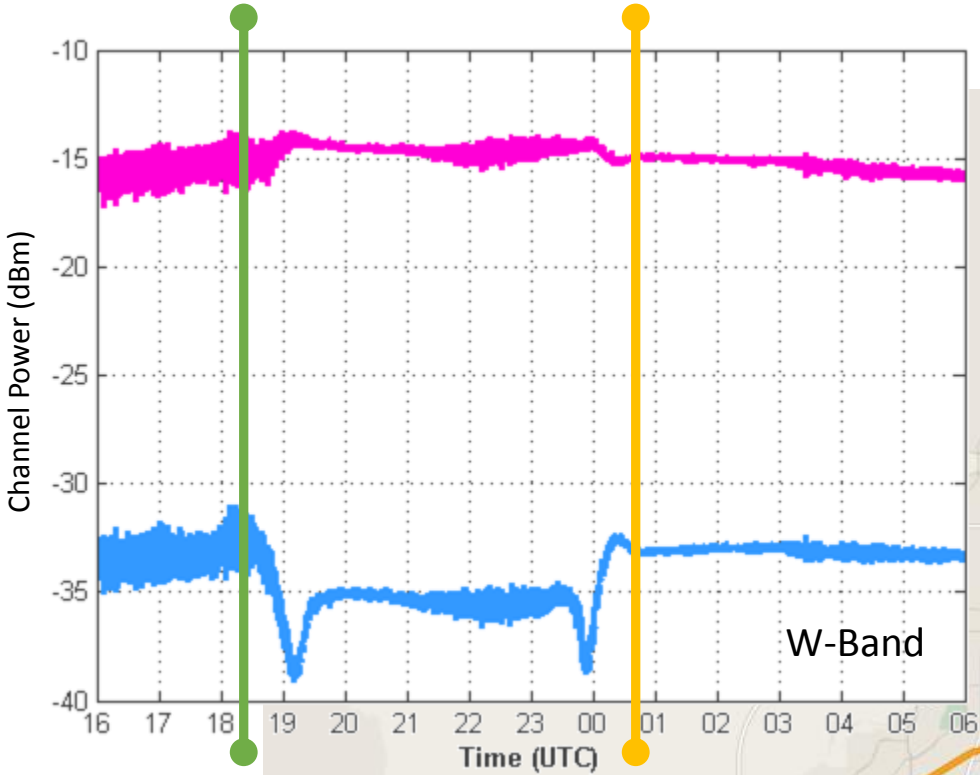
99.9% of the 7 month period, the rain rate was less than 3.513 mm / hr.

In other words, the rain rate was less than 3.513 mm/hr for 90.48% of times when rain was measured.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Total
Occurrence of Rain	2.14%	1.31%	0.79%	1.08%	0.07%	0.05%	2.19%	3.22%	1.05%
99.9% Rain Rate *(Exceeded 0.1% of the Time)*	5.656 mm/hr	4.106 mm/hr	3.399 mm/hr	1.112 mm/hr	0.000 mm/hr	0.000 mm/hr	5.179 mm/hr	0.197 mm/hr	**3.513** mm/hr

* Worst Month
* Best Month(s)

Radome Warming (2015-10-12)



Daily co/x power disturbances were observed, particularly on the W-band, and correlated with solar position. This was remedied by replacing the transmitter radome with a more suitable εr=1 dielectric.

Concluding Remarks & Future Work

Conclusions

- The WTLE terminal has been operational since October 2015, collecting attenuation, scintillation, and depolarization data across a 26 km link in Albuquerque, NM. As of this presentation, **nearly nine months of data have been collected**.
- For **99% of the time, the observed attenuation was less than 16.845 dB (V)** and **22.065 dB (W)**. The worst months in terms of the attenuation were October (V) and November (W), while the best month for both was March (V and W).
- Large monthly variability was observed, with a difference of up to **35.8 dB (V) and 39.8 dB (W)** month-to-month.
- Rain was observed **1.05%** of the time over the analyzed 7 months (61.5 hrs). The rain rate only exceeded 3.5 mm/hr for **5.8 hrs** over the 7 months.

Future Work

- Weather station along the path is currently being installed to assess weather conditions along the link.
- Tandem optical link is planned for the near future to characterize optical propagation with concurrent RF data.

Thank You!

Appendix Charts

Contact Information

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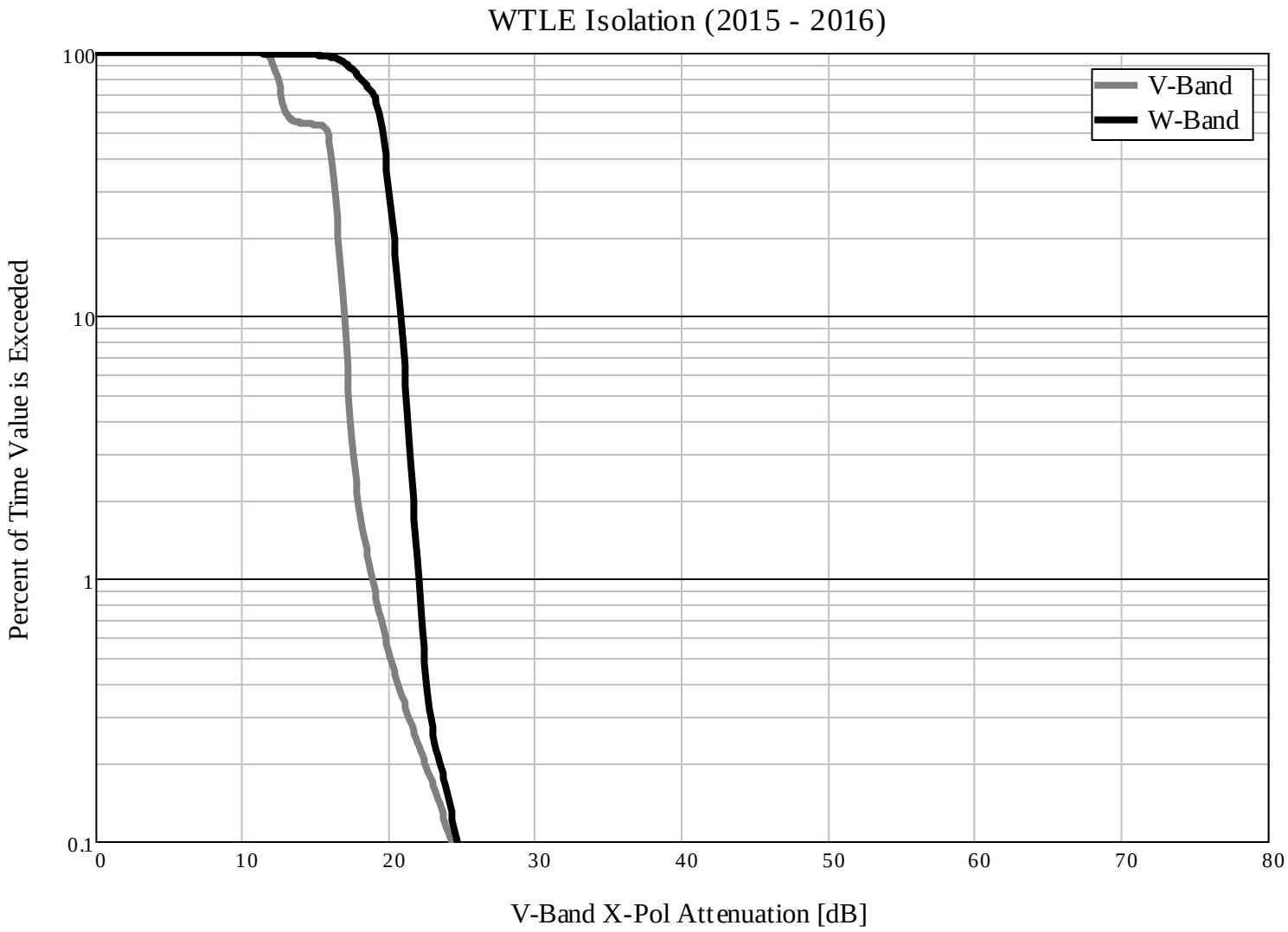
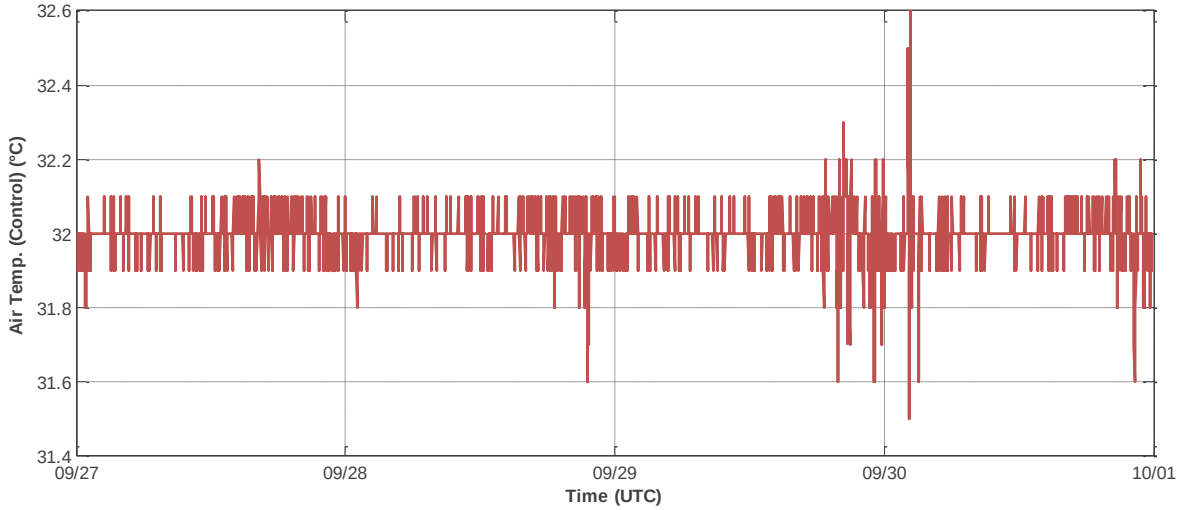
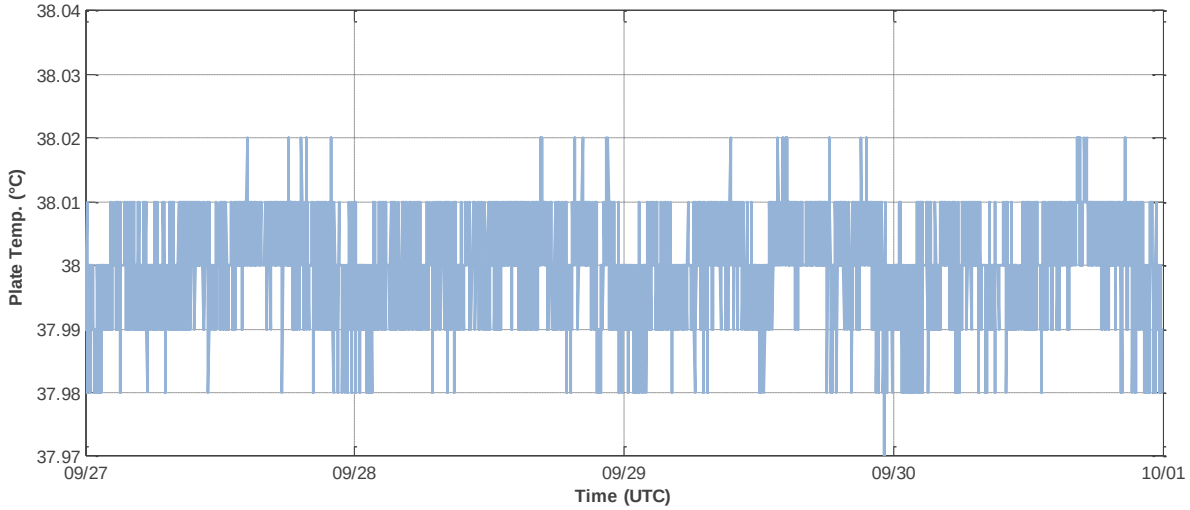
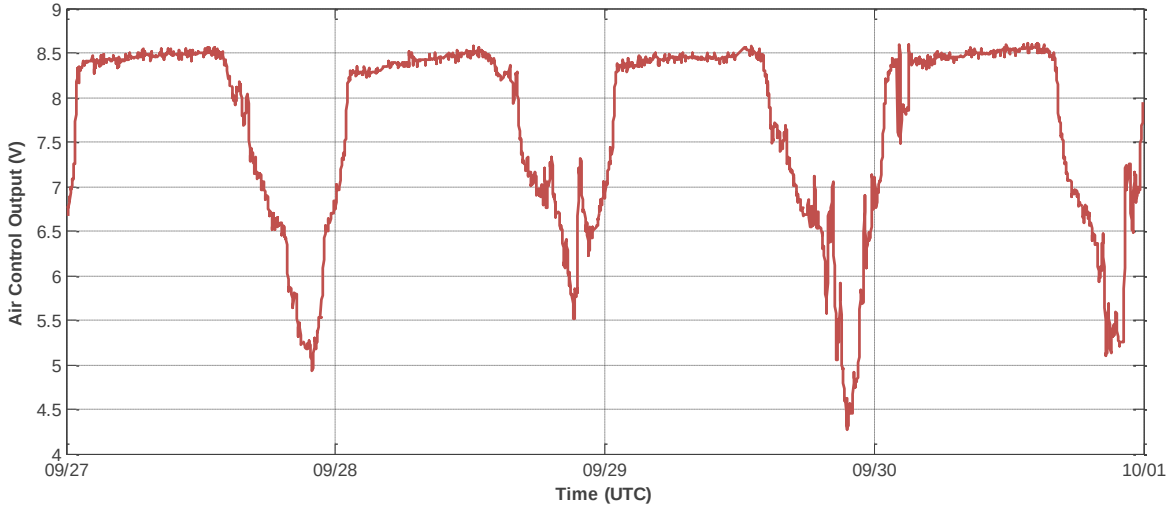
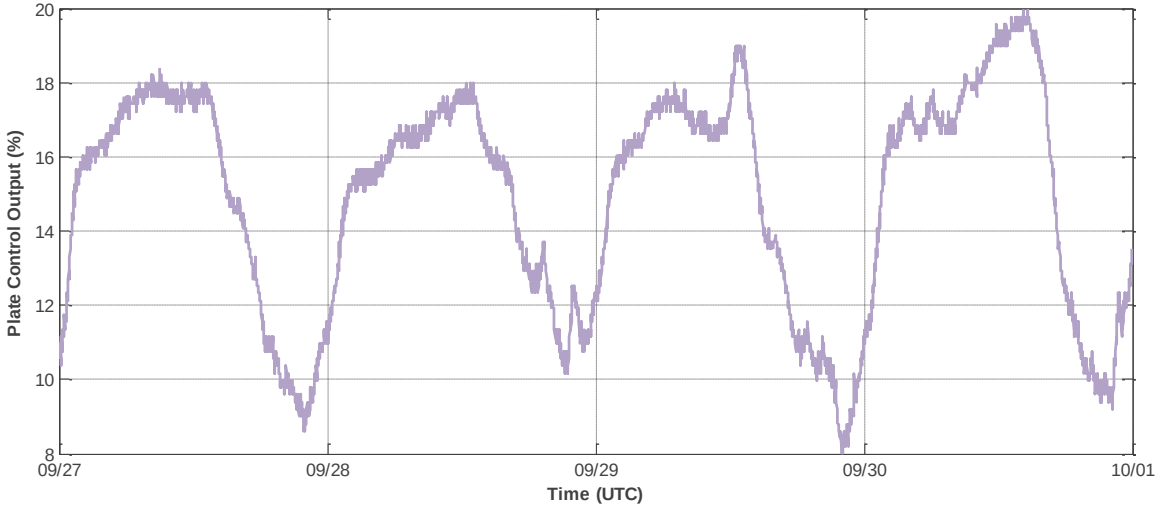

WTLE Isolation (2015 - 2016)
Percent of Time Value is Exceeded
100
10
1
0.1
0
10
20
30
40
50
60
70
80
V-Band X-Pol Attenuation [dB]
V-Band
W-Band

Tx Air & Plate Temperatures and PWM Output

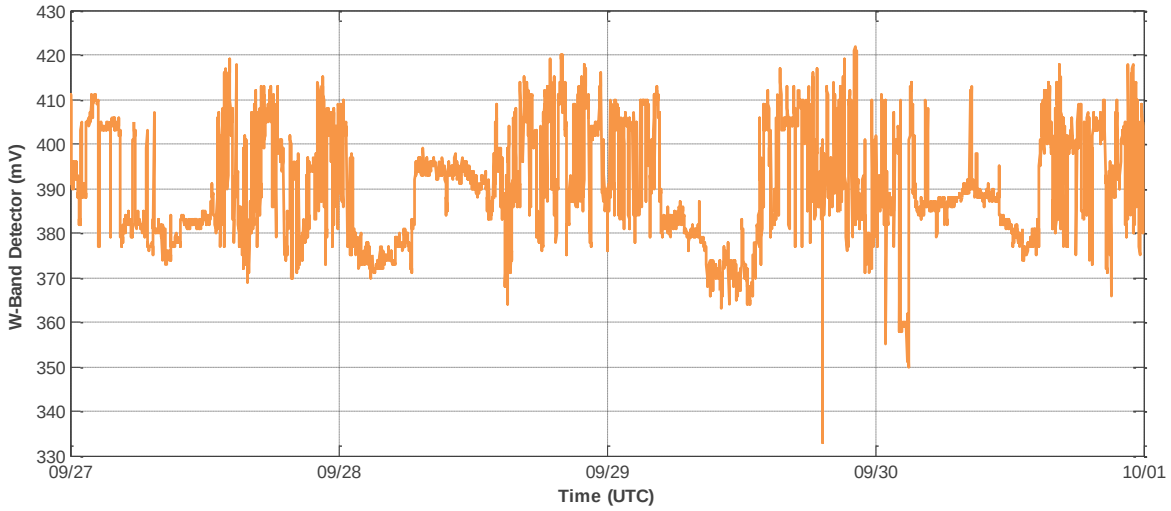


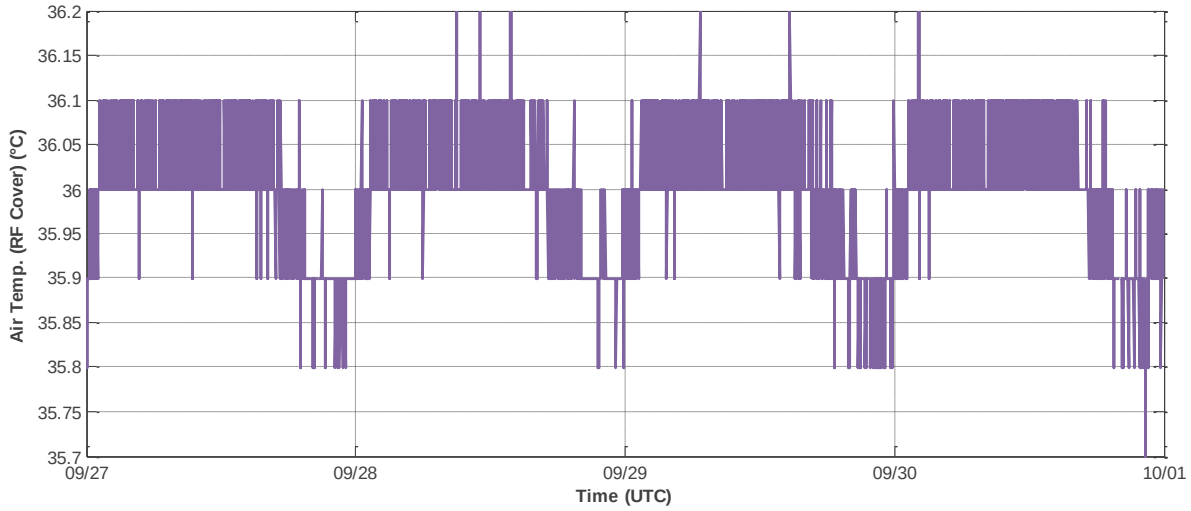


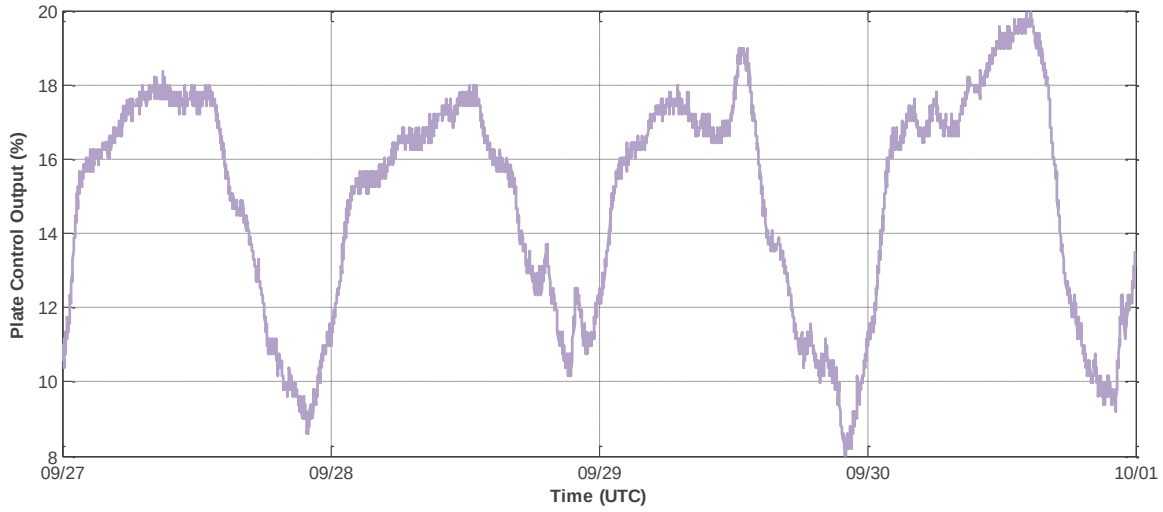


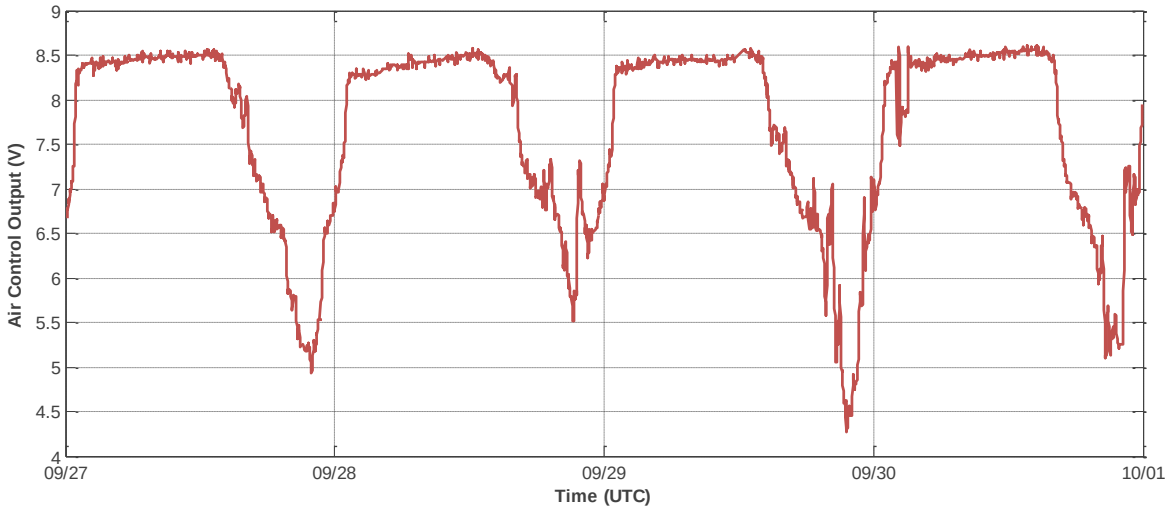


Power Detector Variance & PWM Outputs

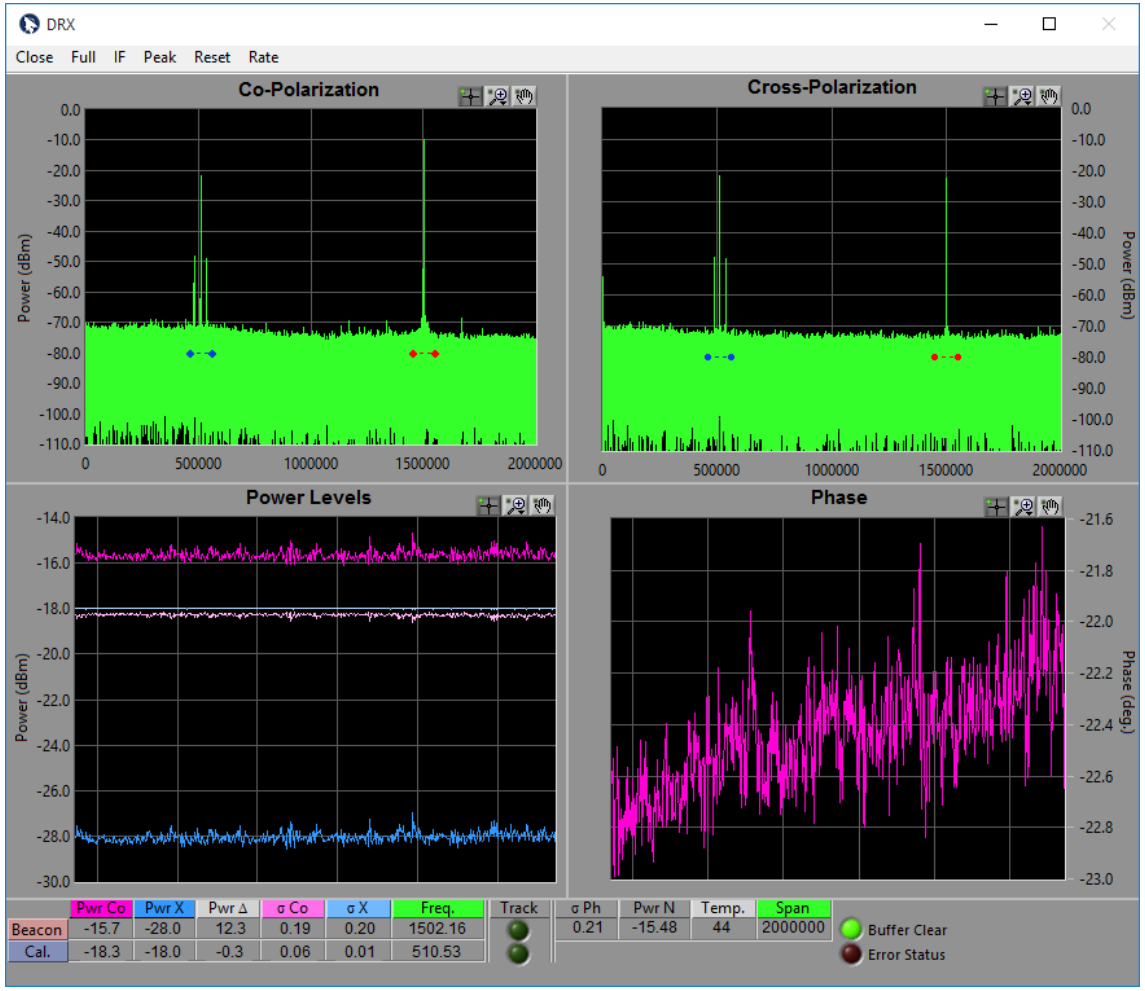








Receiver Software



Tx Power vs. Rx Power (2015-09-29 0600 - 1200)