Preliminary Statistics from the NASA Alphasat Beacon Receiver in Milan, Italy

Convened Session: Results of Ka and Q Band propagation campaigns using Alphasat Aldo Paraboni and other Satellites

Michael J. Zemba
James A. Nessel
Jacquelynne R. Morse

NASA Glenn Research Center
Advanced High Frequency Branch

216.433.5357
michael.j.zemba@nasa.gov

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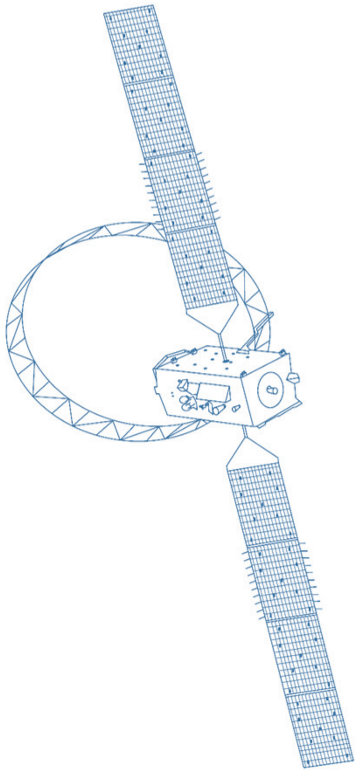
Presentation Overview

1. Motivation & Experiment Goals
2. Site of Study
3. Instrumentation
4. Beacon Receiver Design
5. System Performance
6. Results
7. Concluding Remarks

Motivation & Experiment Goals



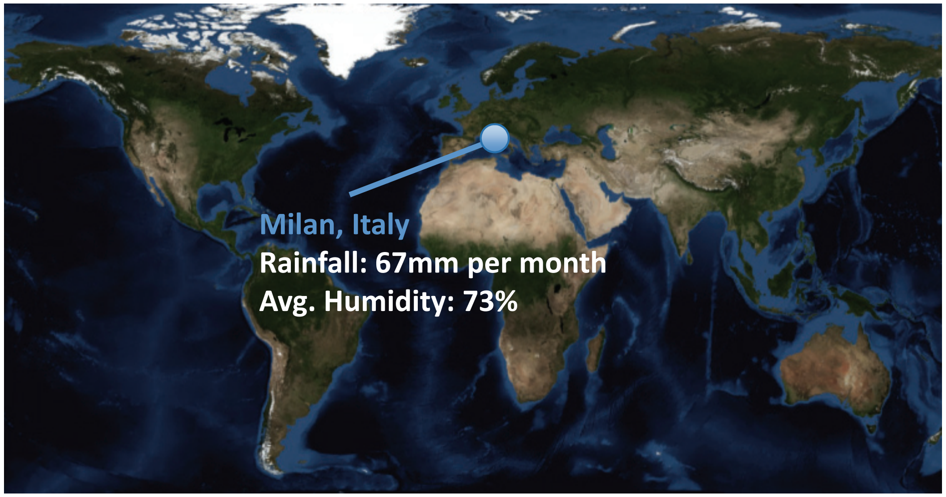
Experiment Goals

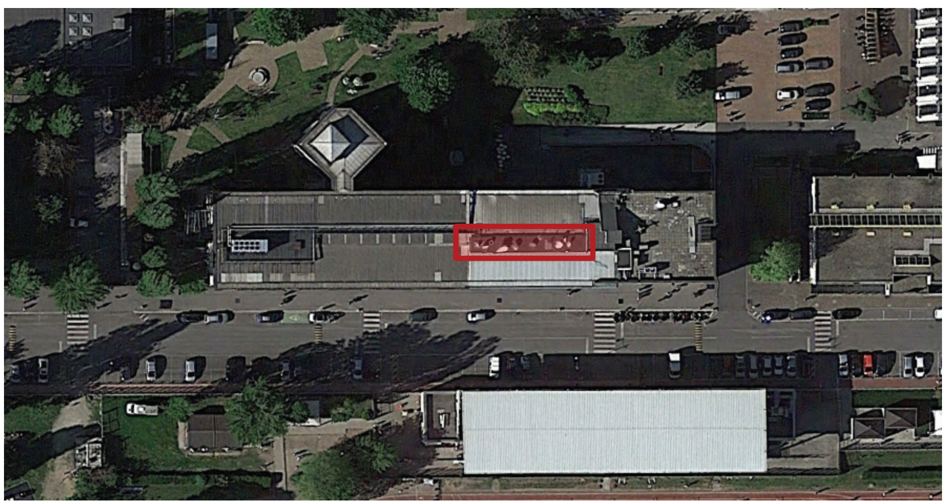
- To assess the impact of rain attenuation and scintillation effects on links operating in the Q-band
- To develop a physical model to improve predictions of atmospheric attenuation within the desired spectrum
- To conduct long term site diversity experiments at Q-band in coordination with Spino d'Adda site

NASA Motivation

- Preliminary architecture studies of the next generation TDRSS system will require higher downlink bandwidths than available in the current Ku-band allocation
- The allocation of 4 GHz of contiguous bandwidth in the Q-band provides an opportunity to meet these requirements

Site of Study





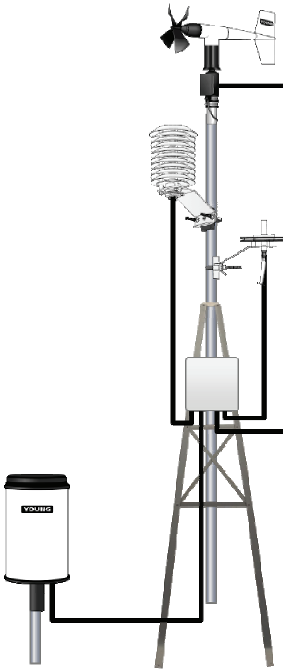
		Milan, Italy
Ground Station	Installation Date	April 2014
	Latitude	45.4787° N
	Longitude	9.2327° E
	Altitude	138 m
Satellite	Name	Alphasat
	Nom. Elevation	35°
	Nom. Azimuth	158°
	Beacon Freqs.	19.701 GHz 39.402 GHz

Instrumentation

Beacon Receivers

Receiver Parameters	Performance Spec.
Antenna Gain	45.6 dBi (Ka / Q-band)
System Noise Temperature	504 K (Ka-band) 720 K (Q-band)
Sampling Rate	8 Hz / 1 Hz (averaged)
Dynamic Range	38 dB (Ka-band) 40 dB (Q-band)
Antenna Tracking Resolution	0.01°

Weather Instrumentation

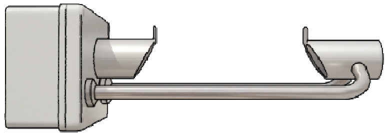


Anemometer:
Young 05178A

Temperature/Humidity Sensor:
Young 41382VC

Pressure Sensor:
Young BPV3000

Tipping Bucket:
Young 52203

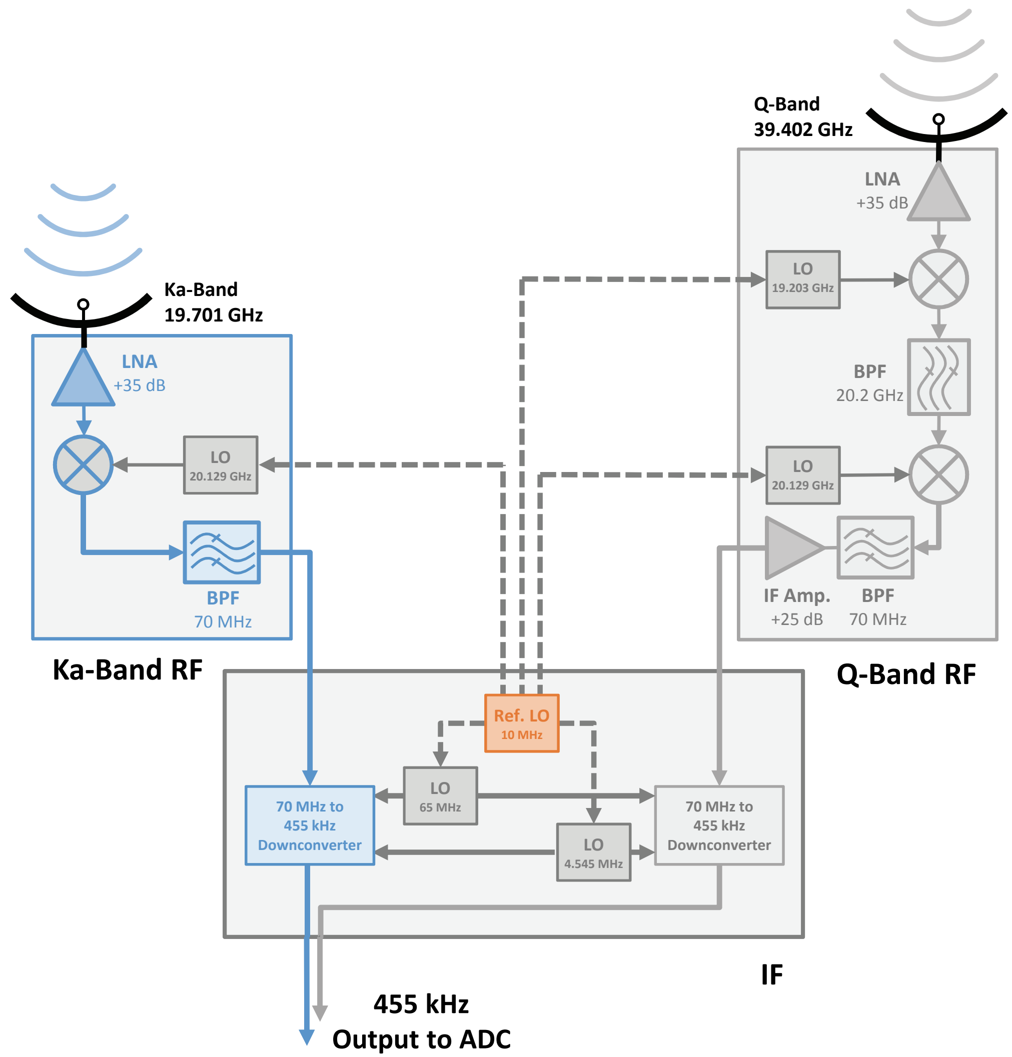


Disdrometer:
Thies Clima 5.4110

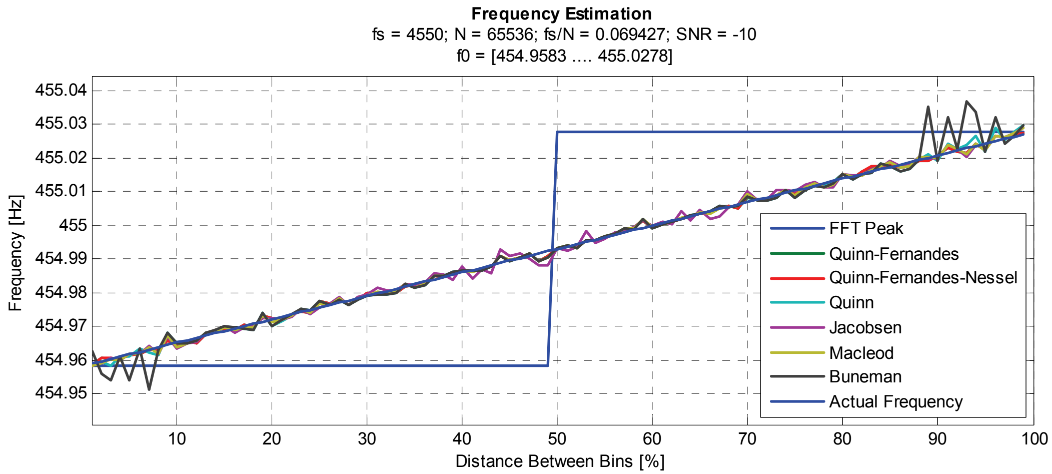
Beacon Receiver Design

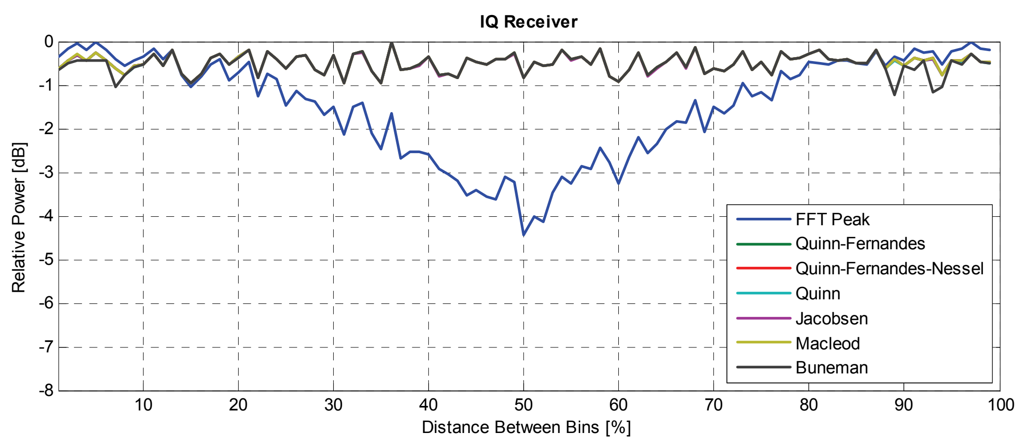
Beacon Receiver Specifications	
Downconversion (Ka)	3-step down to 455 kHz
Downconversion (Q)	4-step down to 455 kHz
ADC Sampling Rate	1.111 MHz
ADC # of Samples	2^{17}
Integration Time	125 ms
Time Series Output Rate	8 Hz / 1 Hz (averaged)

- Common ultra-stable 10 MHz ref. oscillator
- T_{LNA} temperature controlled within ±0.1°C
- $T_{RFplate}$ temperature controlled within ±0.01°C
- T_{IF} temperature controlled within ±0.25°C



Frequency Estimation Approach





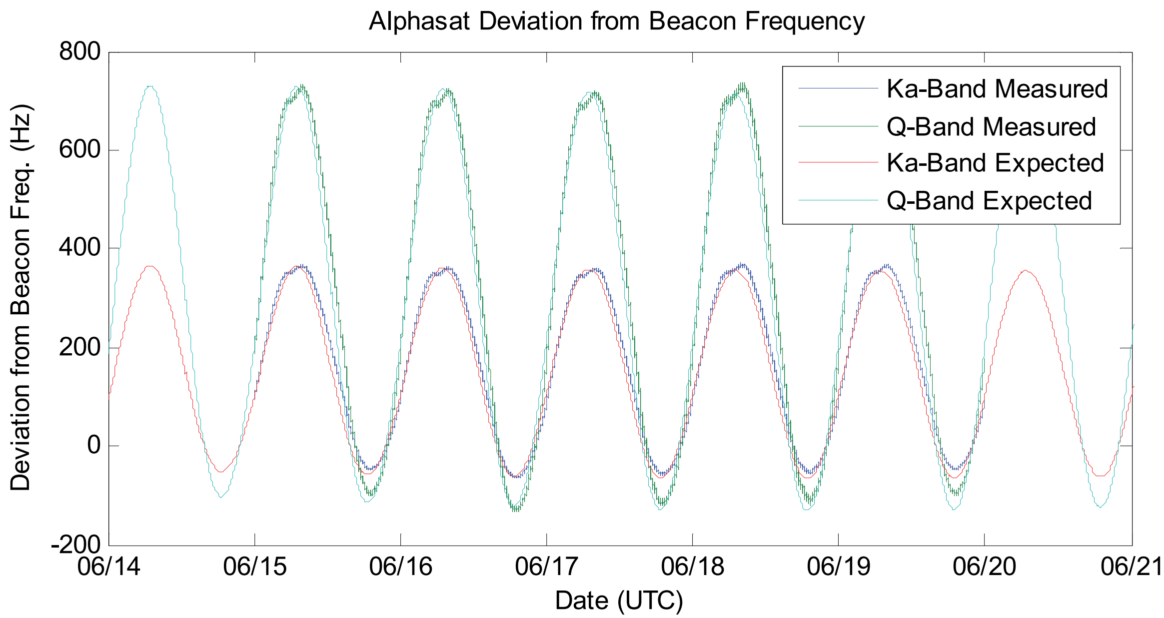
Omission of PLL hardware requires alternate FFT approach to estimate signal power, particularly due to large Doppler effect from Alphasat's inclined orbit.

Frequency estimation algorithms increase resolution of frequency measurement and eliminate the power measurement's sensitivity to frequency drift.

Receiver utilizes a modified Quinn-Fernandes frequency estimation technique to track signal and maintain high dynamic range (~38 dB)

The frequency estimator algorithm used in the receiver is currently pending patent.

Measured Doppler Shift

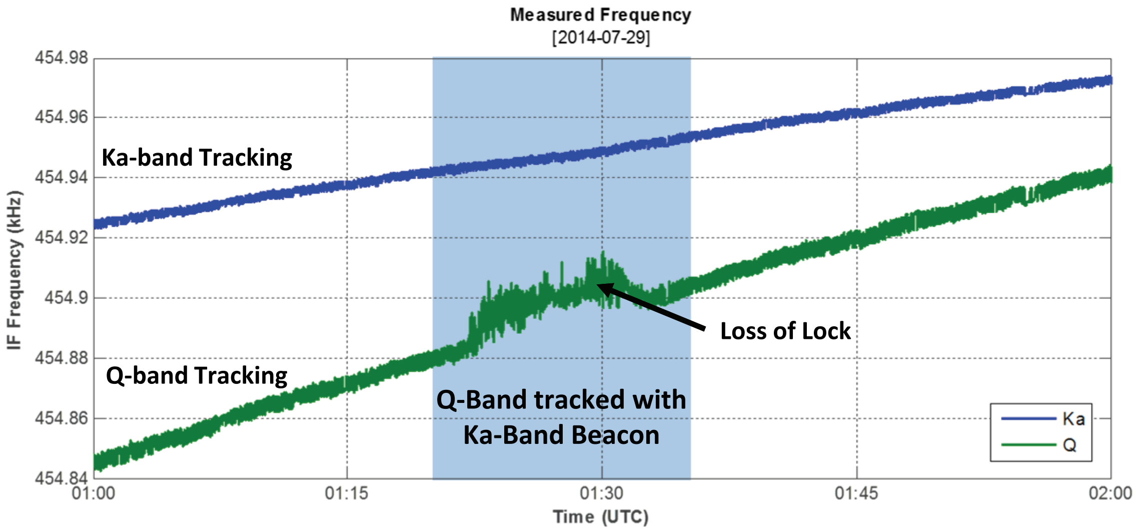


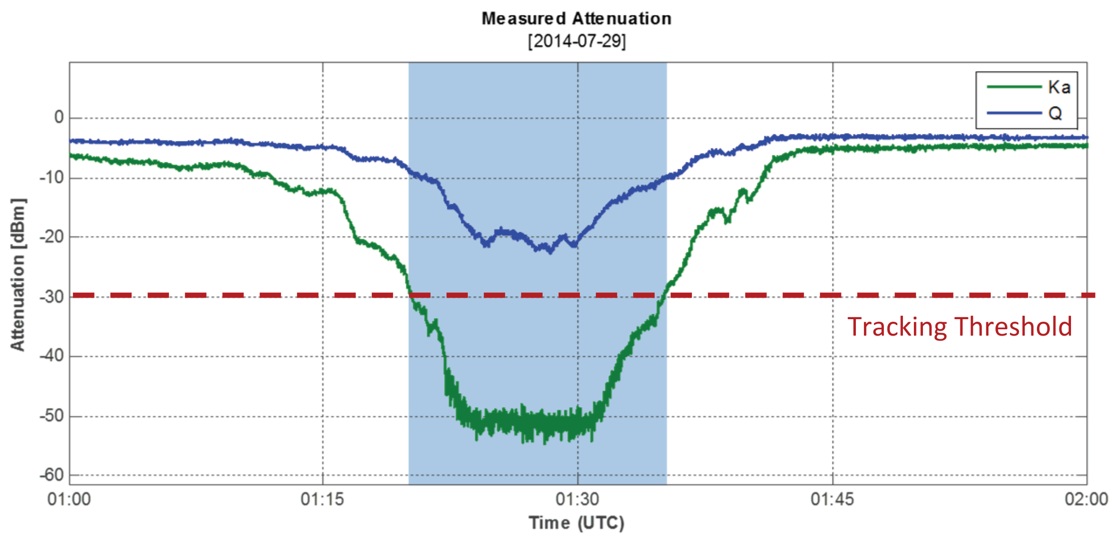
	Drift	Offset
Ka-Band Beacon	15.7 Hz/day	150 Hz
Q-Band Beacon	31.6 Hz/day	300 Hz

Frequency measurement can be compared to the expected Doppler shift (derived from satellite position data) to estimate the drift due to hardware.

Over a five-day period, the Ka-Band beacon exhibited a linear 15.7 Hz/day drift on top of the expected Doppler pattern (31.6 Hz / day for the Q-band). Total offset was 150 Hz (Ka) and 300 Hz (Q).

System Performance





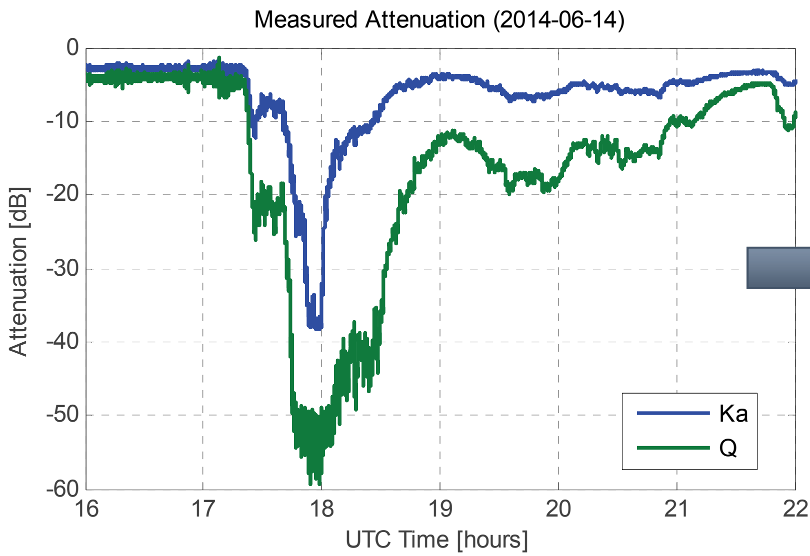
Under normal operating conditions, the K-band and Q-band receivers track their respective beacon signals independently.

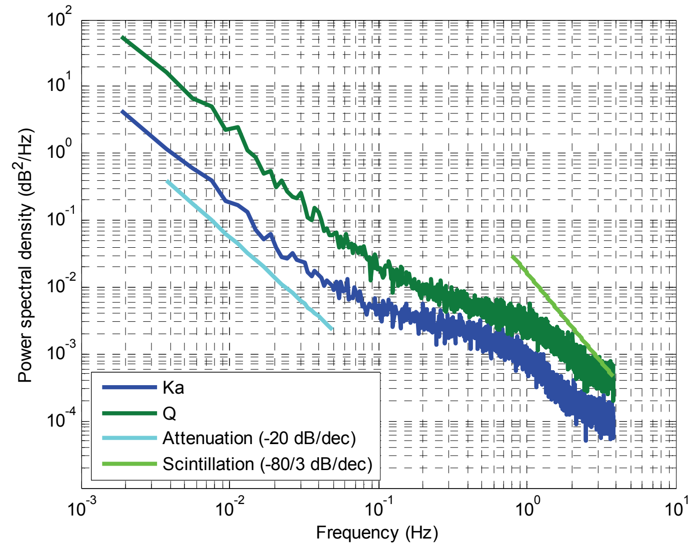
When attenuation exceeds 30 dB on the Q-band channel, the receiver utilizes the coherent K-band channel to maintain lock on the Q-band (region shown in blue).

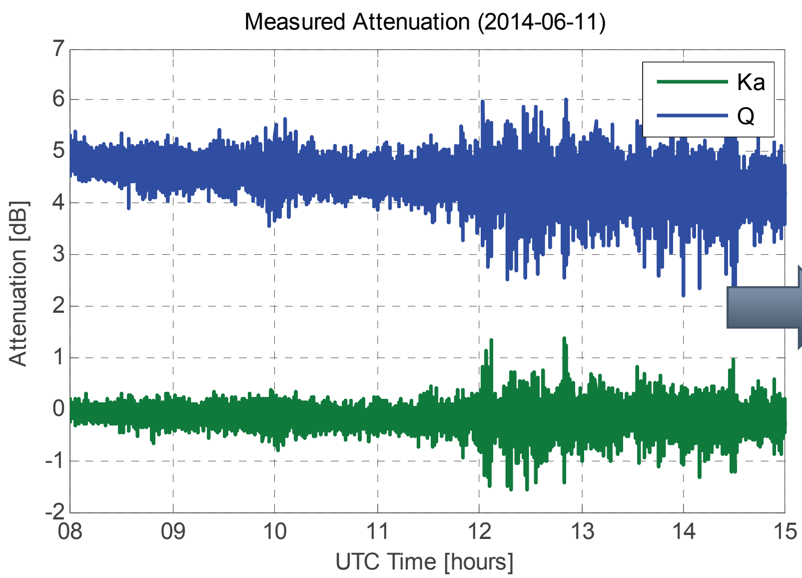
Eventually, for deep rain fades, lock can no longer be maintained and the noise floor of the Q-band receiver is reached.

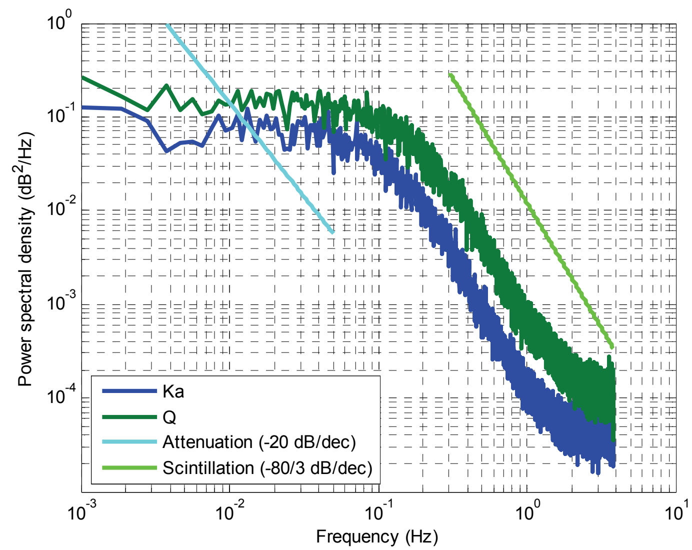
Signal lock is immediately regained when the signal reappears above the noise floor.

Measurement Spectral Density



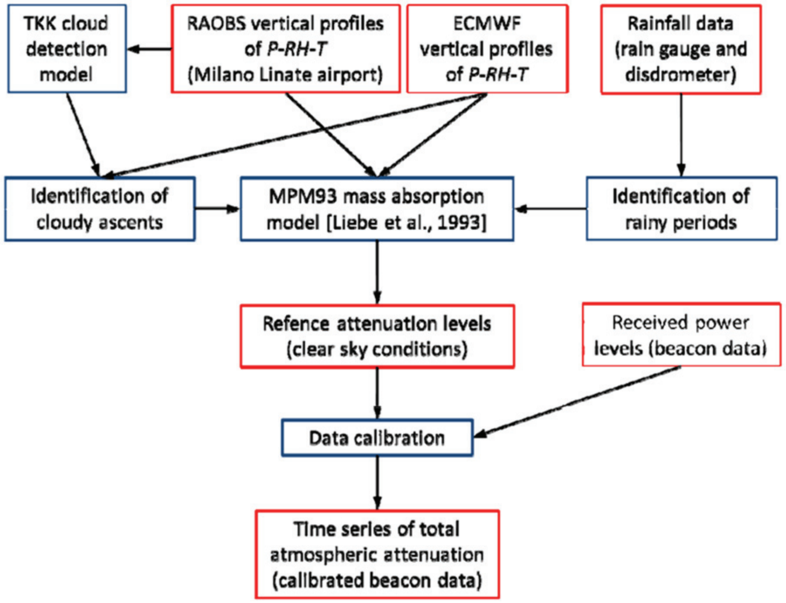


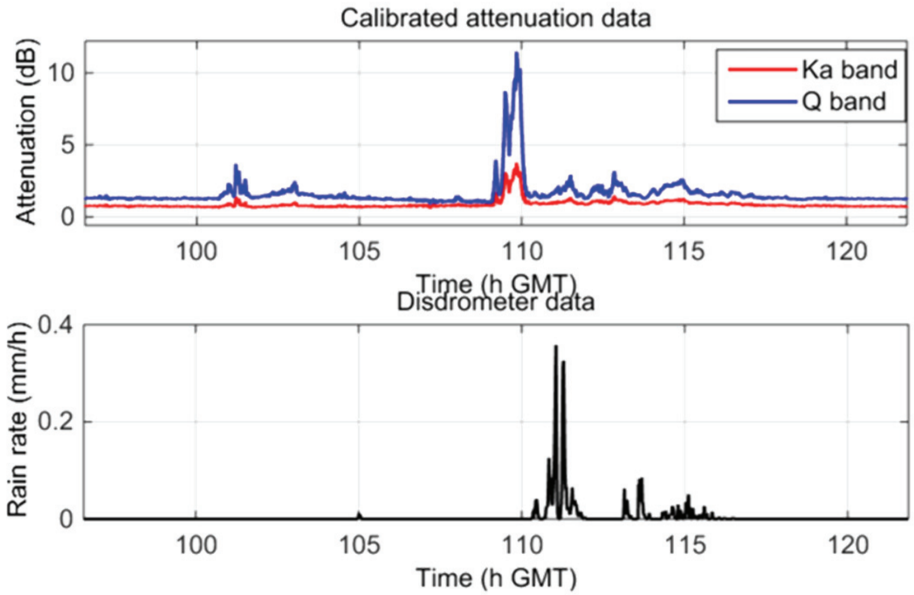




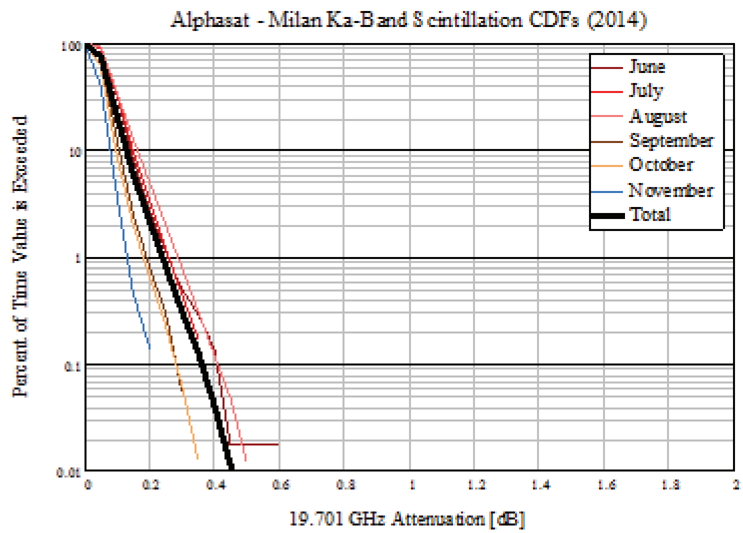
Reference Attenuation Level

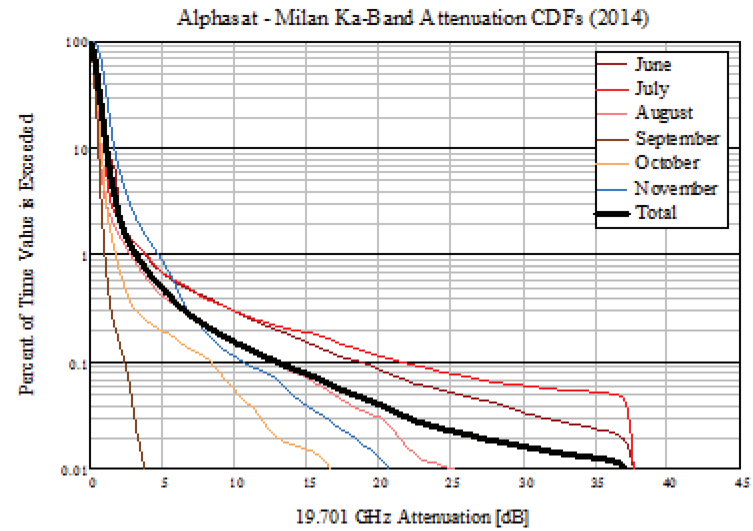
Due to the absence of a radiometer the attenuation reference level is calculated using radiosonde observations and National Weather Prediction products. The total attenuation is them calculated using:

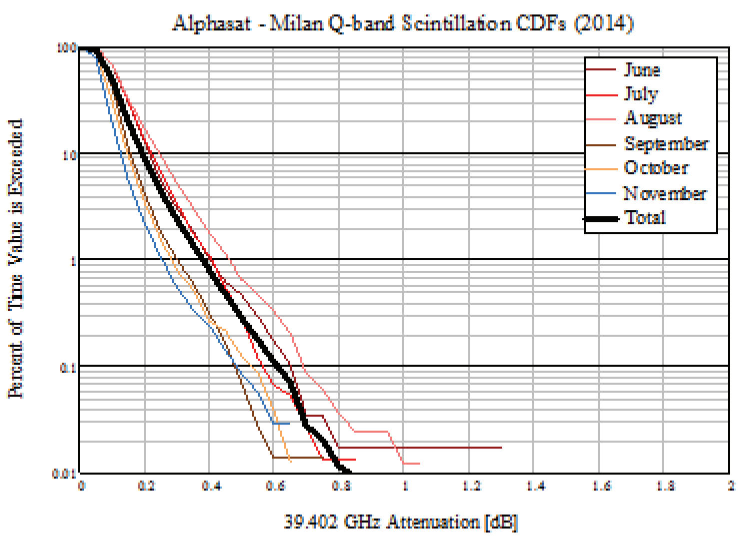


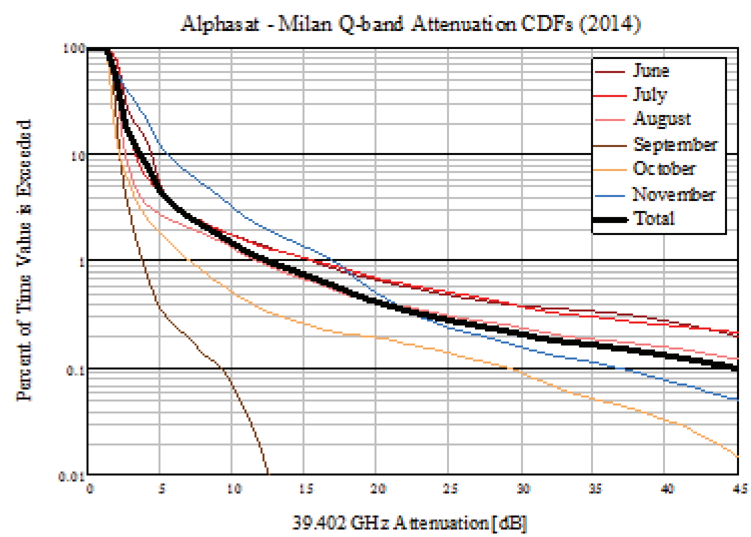


Monthly Results



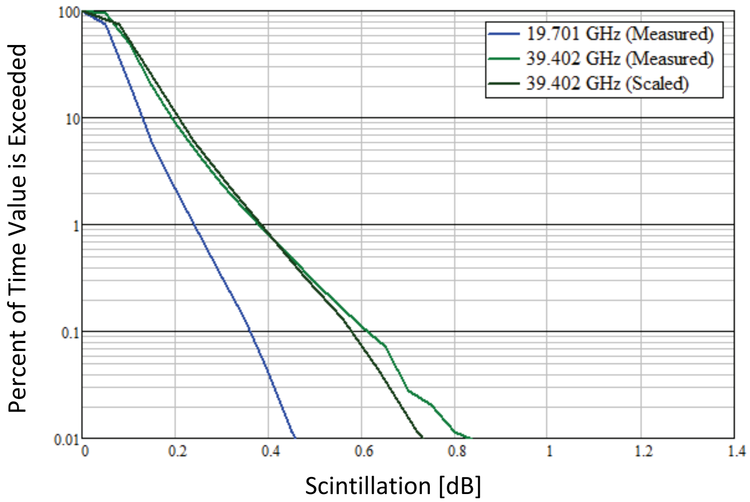




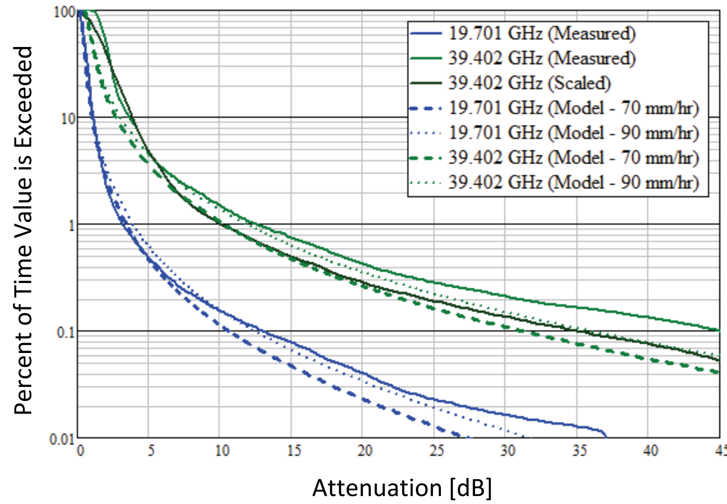


Total Results

Scintillation CDFs



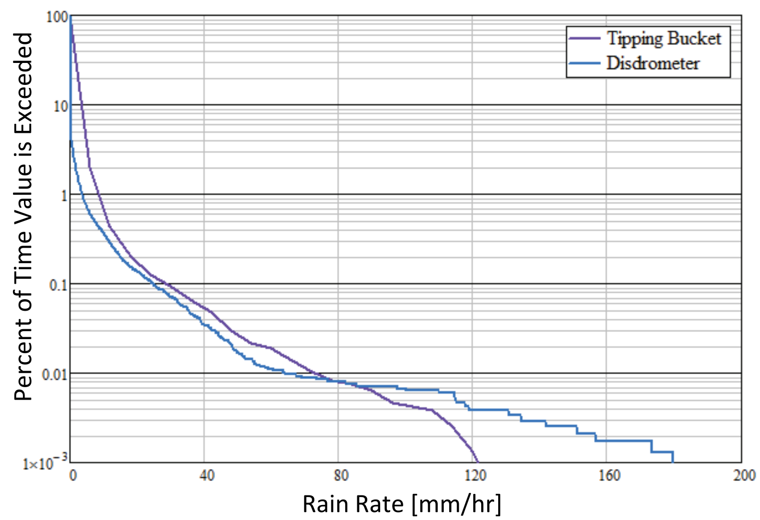
Attenuation CDFs



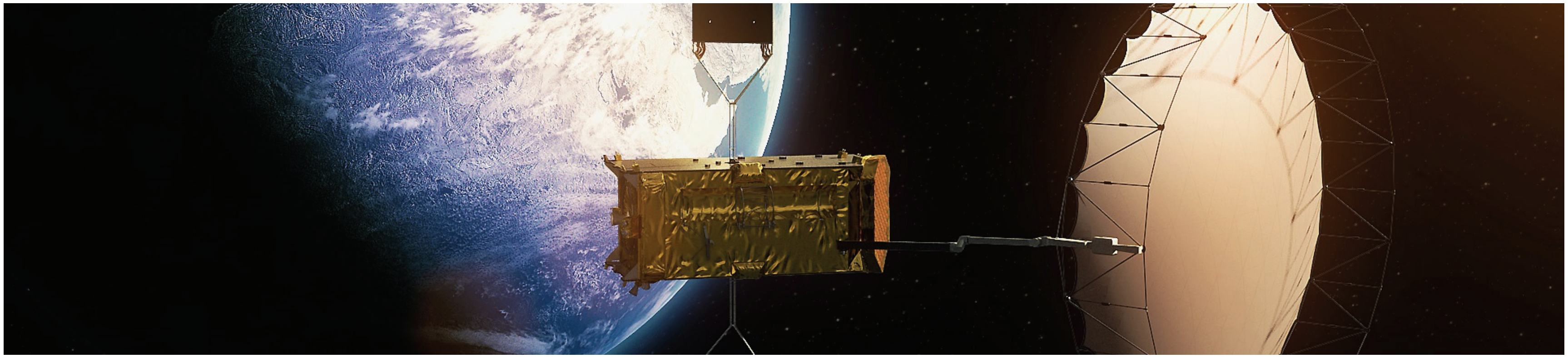
Measurements agree well with the ITU-R P.618-11 model (derived from the rain rate measurements), but start to diverge toward higher availabilities. This may be due to rain events present along the propagation path not detected by the rain sensors, as well as the incomplete year of data collection.

The frequency scaling ratio for scintillation observed in the data was 1.60 and is in close agreement with the expected value of 1.53 suggested by the model.

Rain Rate CDFs

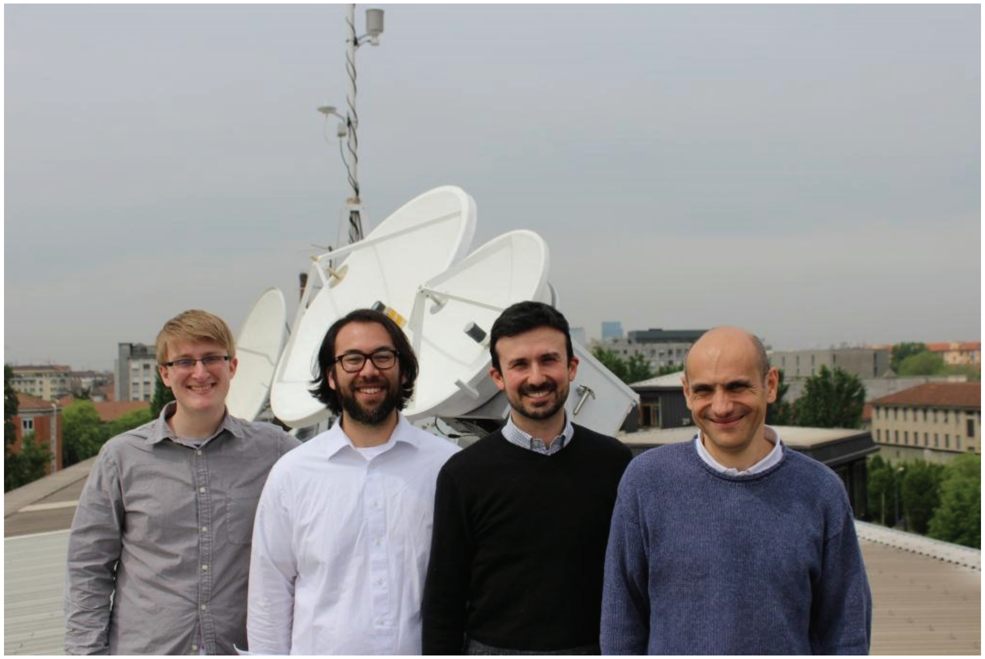


Concluding Remarks



Conclusions:

- Performance of Alphasat propagation terminals has exceeded expectations
- Excepting some unplanned power outages, station has operated reliably since May 2014
- Data collection to continue in Milan for a minimum of 3-5 years to validate and/or update propagation models, and to contribute to ITU databases at higher frequencies
- Planning for installation of water vapor radiometer in 2015 to establish reference levels
- Q-band site diversity measurements (20km baseline) will be available when the second site is operational



THANK YOU!

Appendix Charts

Contact Information

NASA Glenn Research Center
21000 Brookpark Rd. MS 54-1
Cleveland, Ohio 44135, USA

James Nessel
Principal Investigator, RF Propagation Task
216.433.2546
james.a.nessel@nasa.gov

Michael Zemba
Research Engineer
216.433.5357
michael.j.zemba@nasa.gov

Jacquelynne Morse
Research Engineer
216.433.5468
jacquelynne.r.morse@nasa.gov

Link Budgets

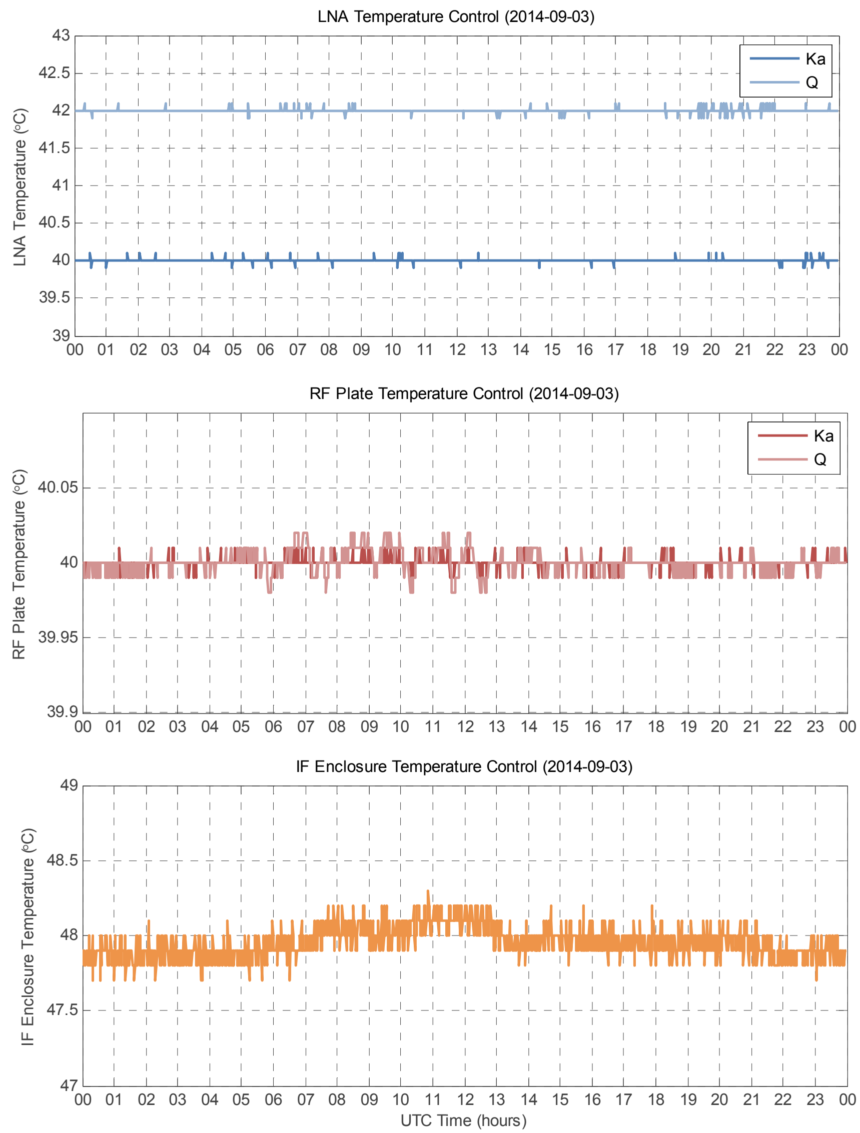
19.701 GHz Beacon

Parameter	User Inputs		Calculated	
Frequency of Operation	19.701	GHz		
Wavelength			0.015	m
Effective Isotropic Radiated Power (EIRP)			**19.50**	**dBW**
Propagation Channel Parameters				
Transmitter → Receiver Range	38600	km		
Gaseous Absorption Loss	0.5	dB		
Rain Attenuation	0.0	dB		
Pointing Loss	0.0	dB		
Polarization Loss	0.0	dB		
Free Space Loss			210.06	dB
Receive Antenna Parameters				
Antenna Diameter	1.2	m		
Illumination Taper Factor	70	deg		
Half Power Beamwidth			0.888	deg
Antenna Efficiency	60	%		
Antenna Gain			45.66	dB
Noise Temperature Contributions:				
Cosmic Background Noise Temperature	2.8	K		
Atmosphere Physical Temperature	290	K		
Antenna Noise Temperature (Clear Sky)			34.03	K
Antenna Noise Temperature (Rain)			34.03	K
Receiver Noise Temperature	600	K		
System Temperature			634.03	K
			28.02	dBK
Boltzmann's Constant			-228.60	dBW/K·Hz
Noise Spectral Density			-200.58	dB
Gain over Noise Temperature Ratio (G/T)			**17.63**	**dB/K**
Received Carrier Power (C)			**-145.41**	**dBW**
Carrier to Noise Density (C/N0)			**55.17**	**dBHz**

39.402 GHz Beacon

Parameter	User Inputs		Calculated	
Frequency of Operation	39.402	GHz		
Wavelength			0.008	m
Effective Isotropic Radiated Power (EIRP)			**26.50**	**dBW**
Propagation Channel Parameters				
Transmitter → Receiver Range	38600	km		
Gaseous Absorption Loss	0.5	dB		
Rain Attenuation	0.0	dB		
Pointing Loss	0.0	dB		
Polarization Loss	0.0	dB		
Free Space Loss			216.08	dB
Receive Antenna Parameters				
Antenna Diameter	0.6	m		
Illumination Taper Factor	70	deg		
Half Power Beamwidth			0.888	deg
Antenna Efficiency	60	%		
Antenna Gain			45.66	dB
Noise Temperature Contributions:				
Cosmic Background Noise Temperature	2.8	K		
Atmosphere Physical Temperature	290	K		
Antenna Noise Temperature (Clear Sky)			34.03	K
Antenna Noise Temperature (Rain)			34.03	K
Receiver Noise Temperature	800	K		
System Temperature			834.03	K
			29.21	dBK
Boltzmann's Constant			-228.60	dBW/K·Hz
Noise Spectral Density			-199.39	dB
Gain over Noise Temperature Ratio (G/T)			**16.44**	**dB/K**
Received Carrier Power (C)			**-144.43**	**dBW**
Carrier to Noise Density (C/N0)			**54.96**	**dBHz**

Hardware Temperature Stability

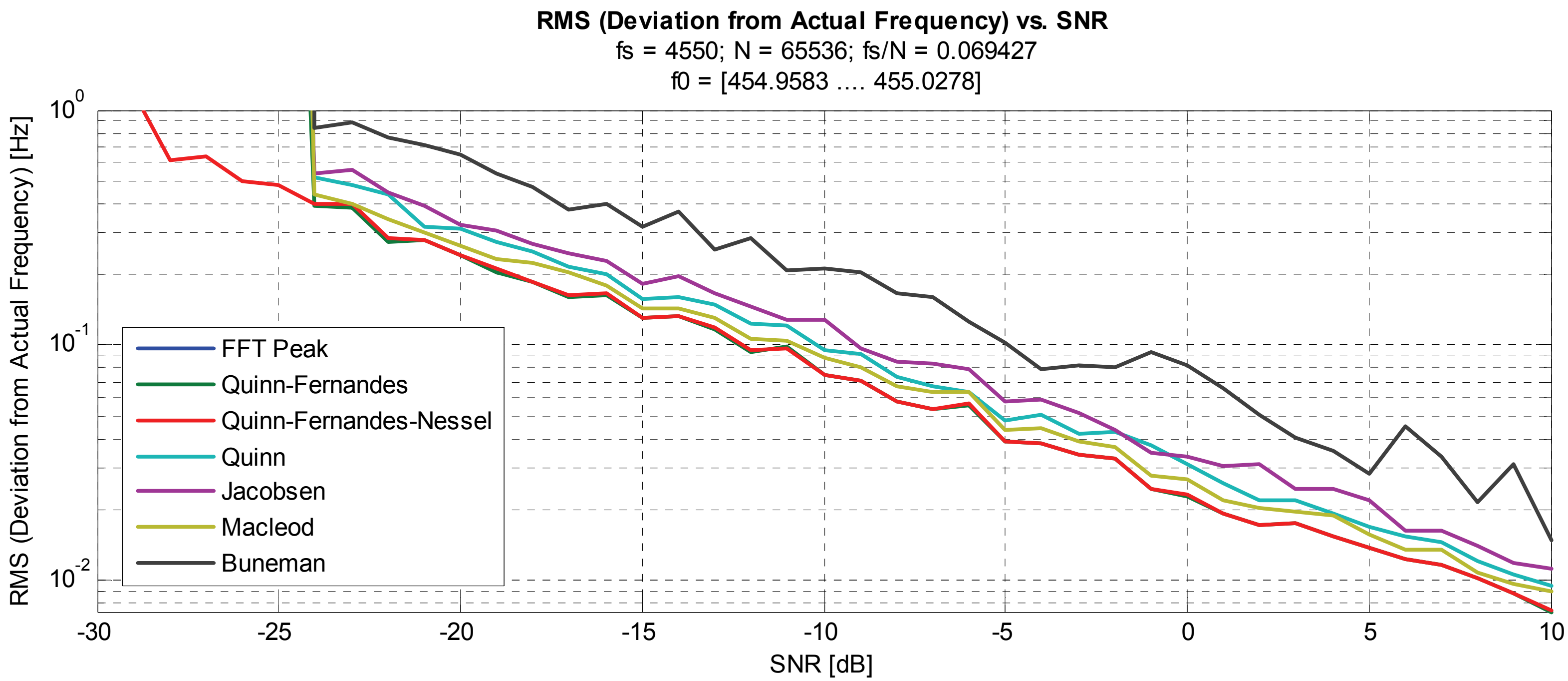


T_{LNA} ±0.1°C

$T_{RFplate}$ ±0.01°C

T_{IF} ±0.25°C

Frequency Estimator Comparison



System Check Out

Passband Calibration

- Diurnal power drift in data was identified to be a result of nonlinear frequency response in the passband of the downconverter cards
- Calibration procedure was developed to estimate power drift as a function of frequency drift and is corrected in post processing

Calibration Procedure:

- Point antennas to zenith and take decimated FFT spectrum for 2 hours (min.)
- Average the spectrum and fit an 8^{th}-order polynomial across passband