A 183 GHz Humidity Sounding Radar Transceiver

ACT-13

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Ken Cooper, Matt Lebsock, Jose Siles, Raquel Monje, Luis Millan, Choonsup Lee, Pekka Kangaslahti, Goutam Chattopadhyay, Robert Lin, David Gonzalez, & Simone Tanelli

Jet Propulsion Laboratory, California Institute of Technology

Scientific Motivation

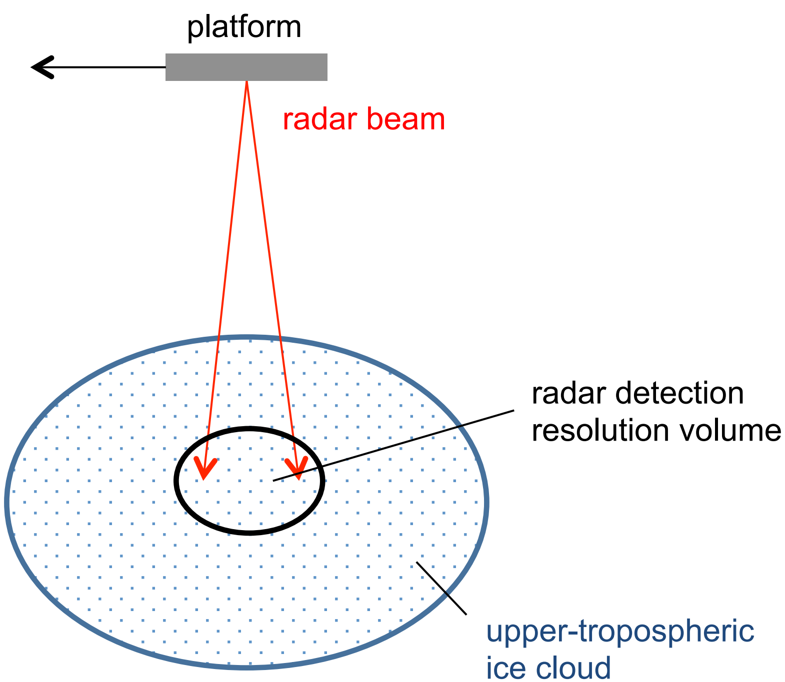
- Clouds are the single most important source of uncertainty in predictions of climate sensitivity.

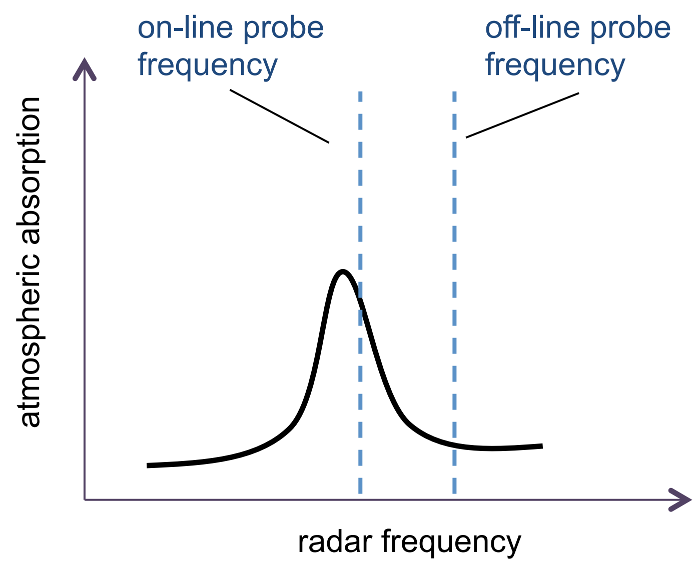
- Problem: passive radiometry is unreliable inside clouds because: (1) broad weighting functions are used that encompass both clouded and cloud-free regions and (2) clouds obscure the relationship between passive brightness temperatures and water vapor.

- Therefore, a remote sensing instrument capable of measuring humidity inside cirrus clouds on a global scale is needed.

JPL's Approach: 183 GHz Differential Absorption Radar

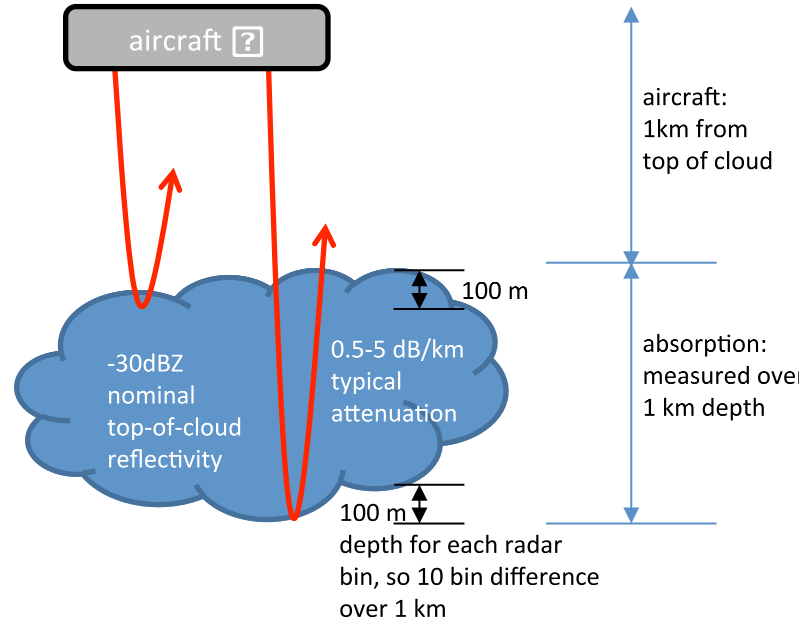
- *Concept*: use the scattering of ice crystals in cirrus clouds to measure range-resolved differential absorption of radar signals on and off the 183 GHz water line.
- Similar to widely used lidar techniques (DIAL) and microwave differential absorption at 60 GHz to measure integrated O_2 absorption from sea surface reflection.



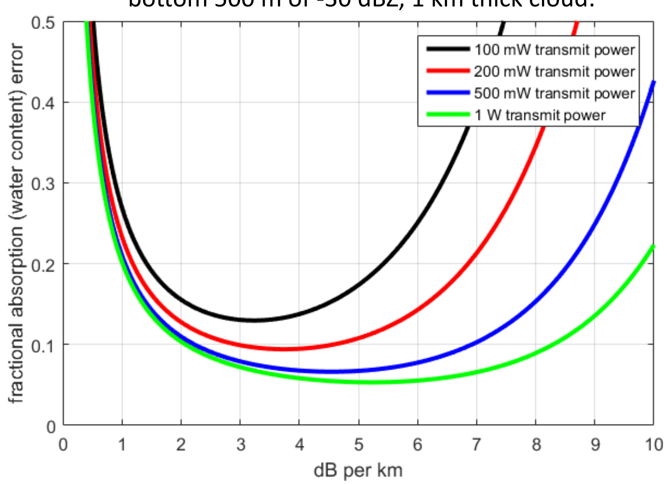


Radar Sensitivity Analysis

	Airborne
along-track resolution	500 m
cloud thickness resolution	500 m
platform velocity	110 m/s
receiver noise figure	8 dB
antenna diameter	25 cm
distance from cloud top	0.5-1 km
cloud top reflectivity	-30 dBZ



bottom 500 m of -30 dBZ, 1 km thick cloud:

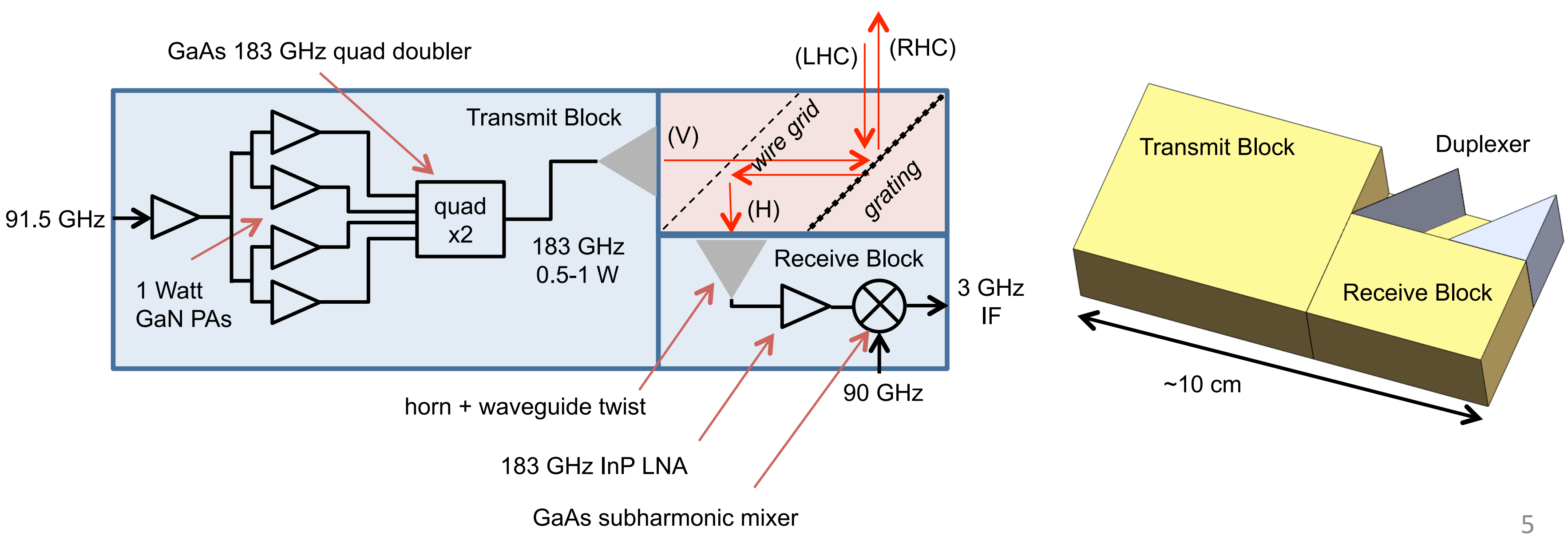


0.1-1 W power levels give reasonable humidity estimates with 1 km integrated range. 1 W clearly probes wider/deeper regime.

What's Needed to Make It Work

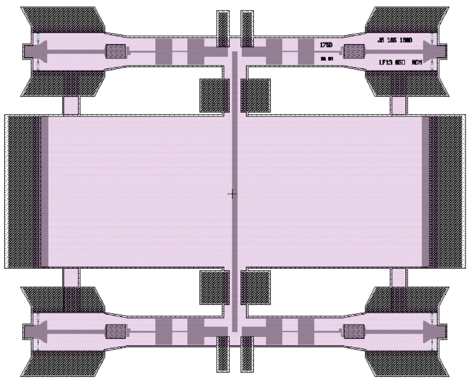
High-level overview:

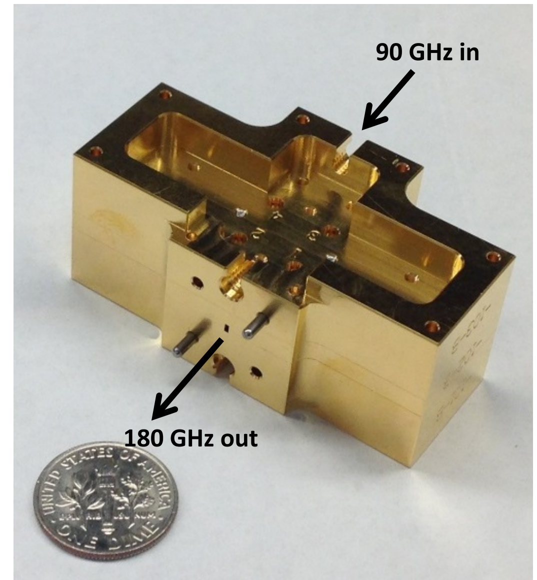
- All-solid-state transmitter & receiver to achieve smallest SWAP.
- Ultra-high transmit/receive isolation for continuous-wave measurements.
- Wide tunability over the 183 GHz water line for probing a variety of cloud densities and depths.



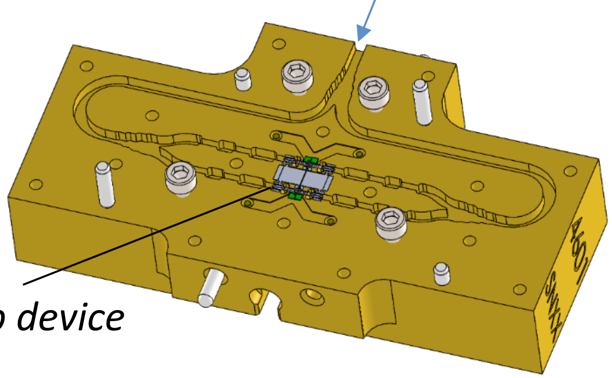
Power-Combining at 183 GHz

Four-way “on-chip” power combining



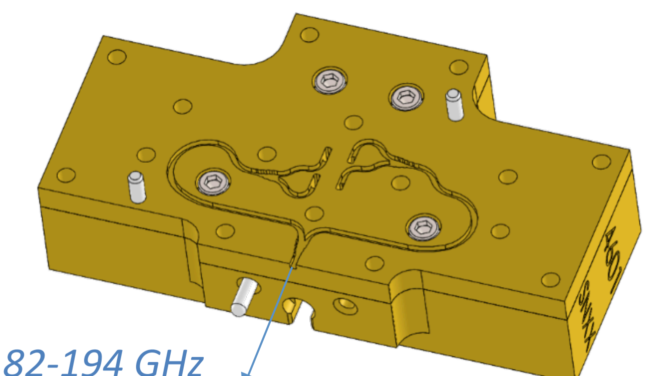


91-97 GHz input



quad-chip device

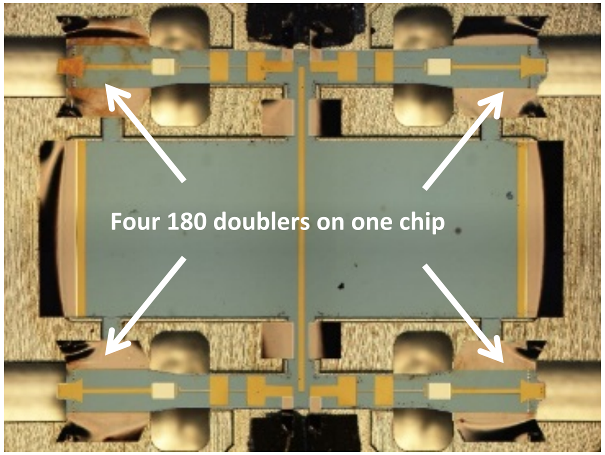
bottom layer

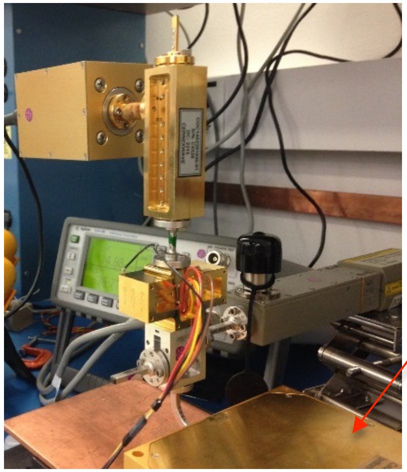


182-194 GHz output

top layer

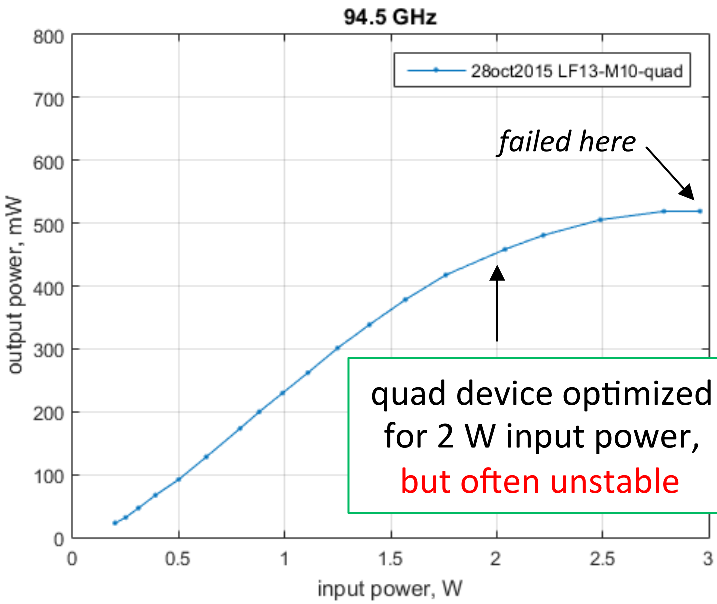
Quad-Chip 183 GHz Doubler



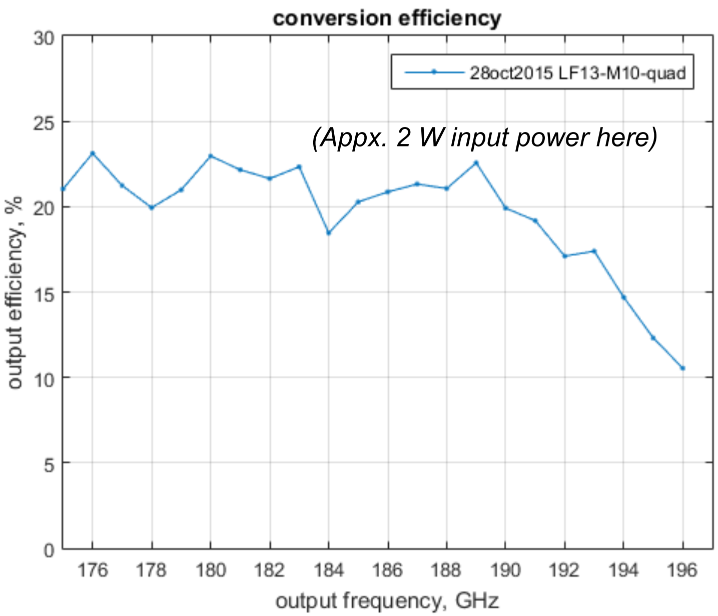


Raytheon 92 GHz GaN power amplifiers: leveraging security for remote sensing science.

A. Brown, et al., "W-Band GaN Power Amplifier MMICs," 2011 IEEE MTTS-S International Microwave Symposium (2011).

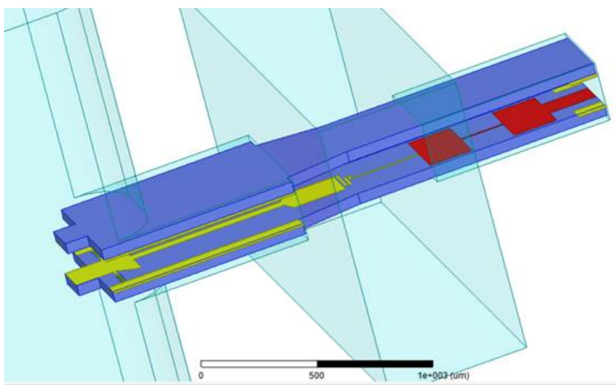


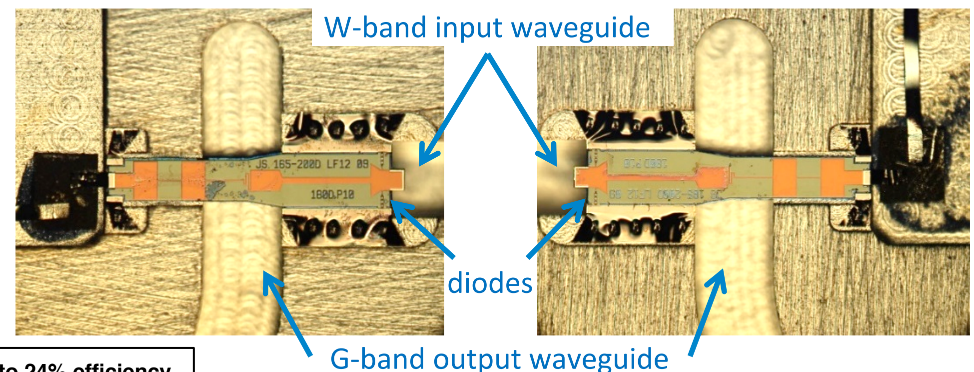
quad device optimized for 2 W input power, but often unstable

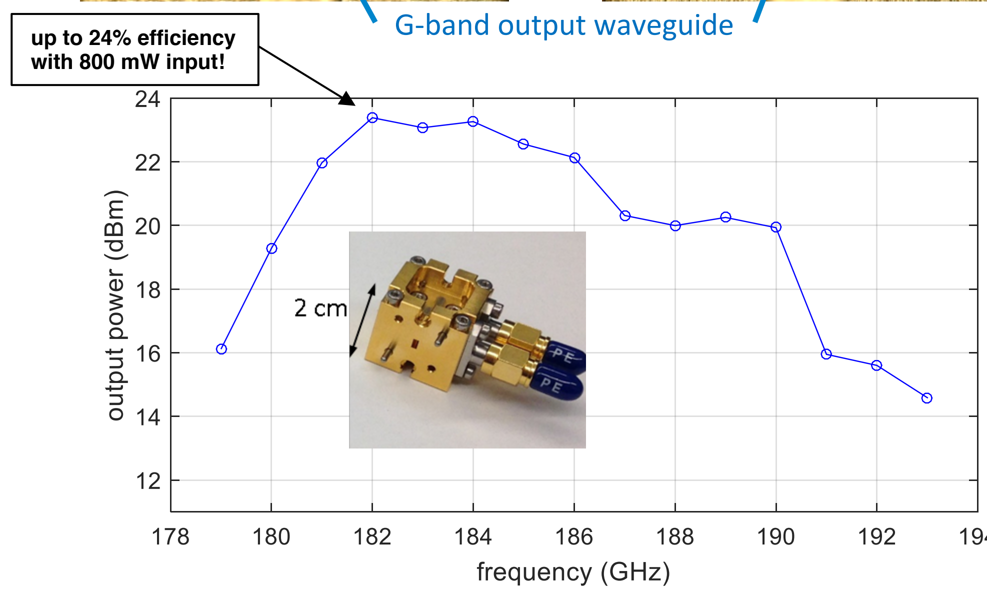


Stacked-Chip Power Combining

- Higher powers likely if we push it
- Stable with 1.2W drive power (210 mW output) for >100 minutes
- 1 W goal is within reach with power-combining

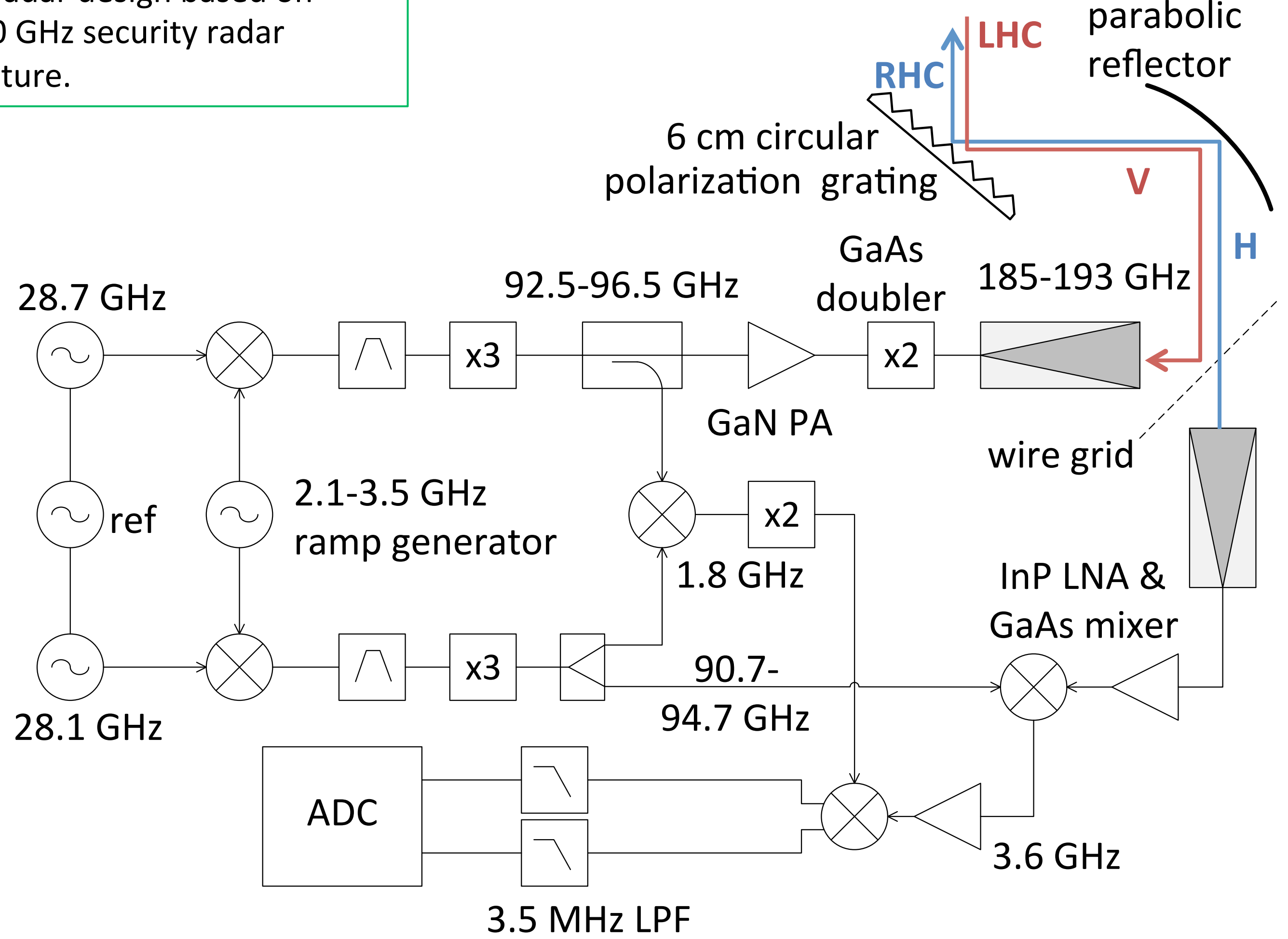




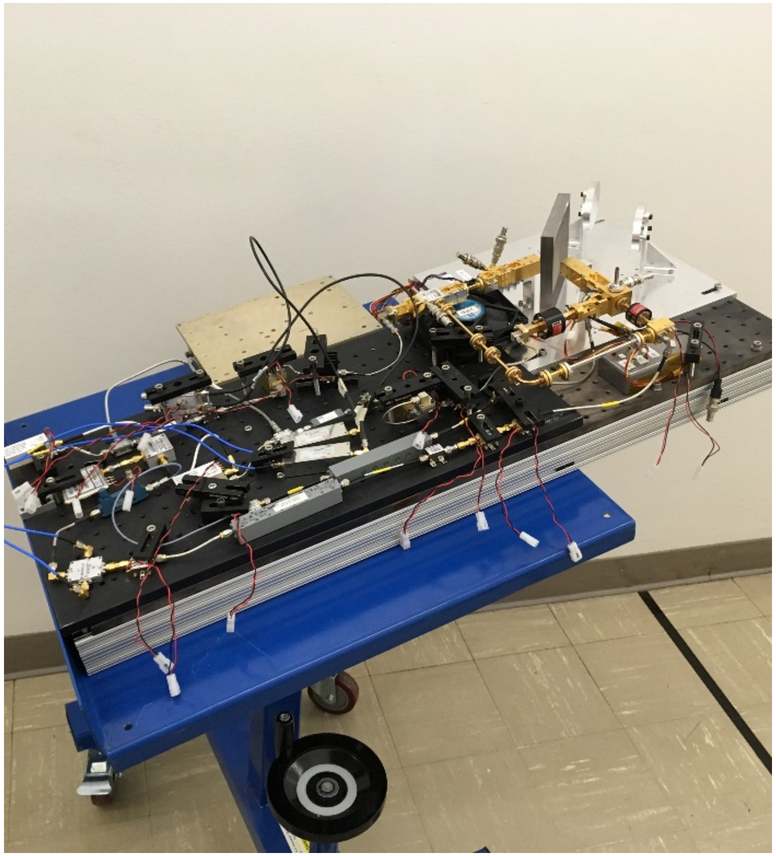


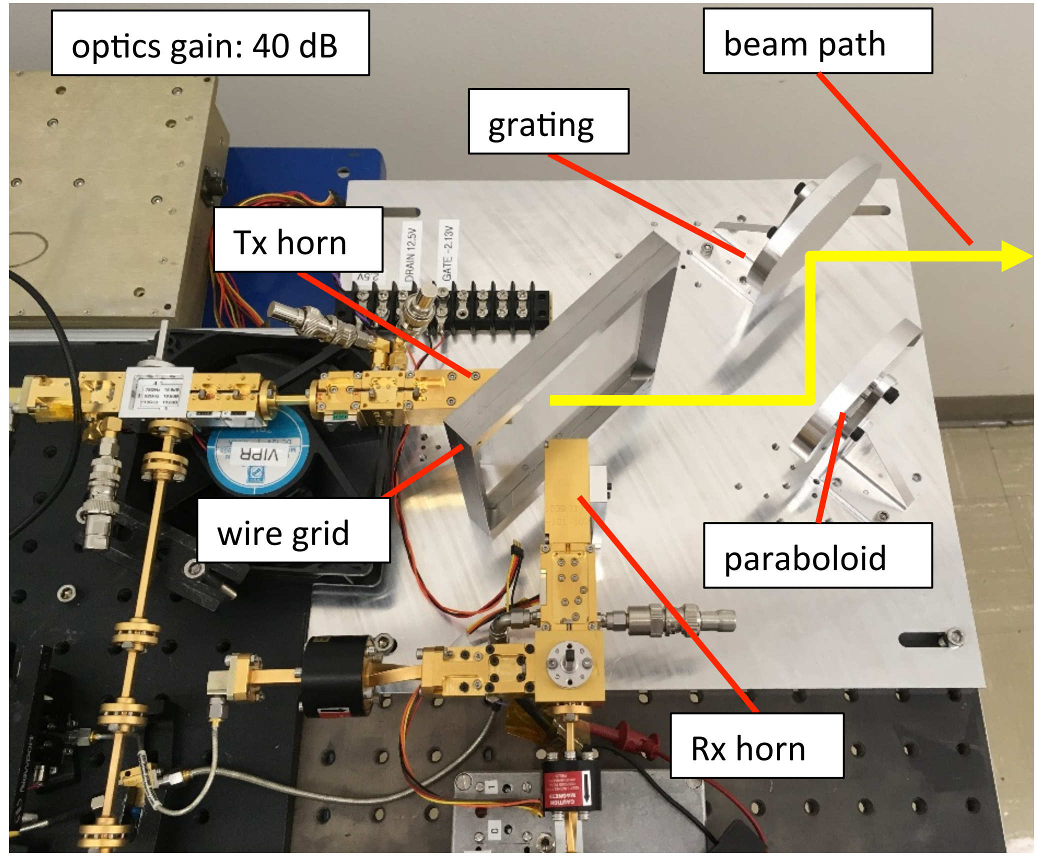
183-193 GHz Radar Test-Bench: Block Diagram

FMCW radar design based on 340/680 GHz security radar architecture.



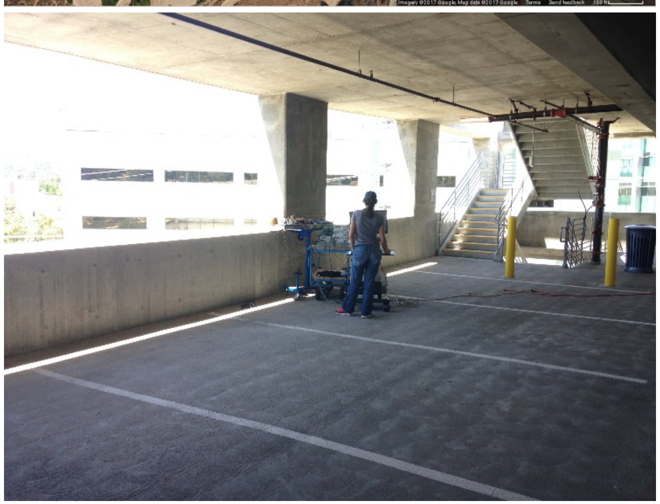
183-193 GHz Radar Test-Bench: Hardware

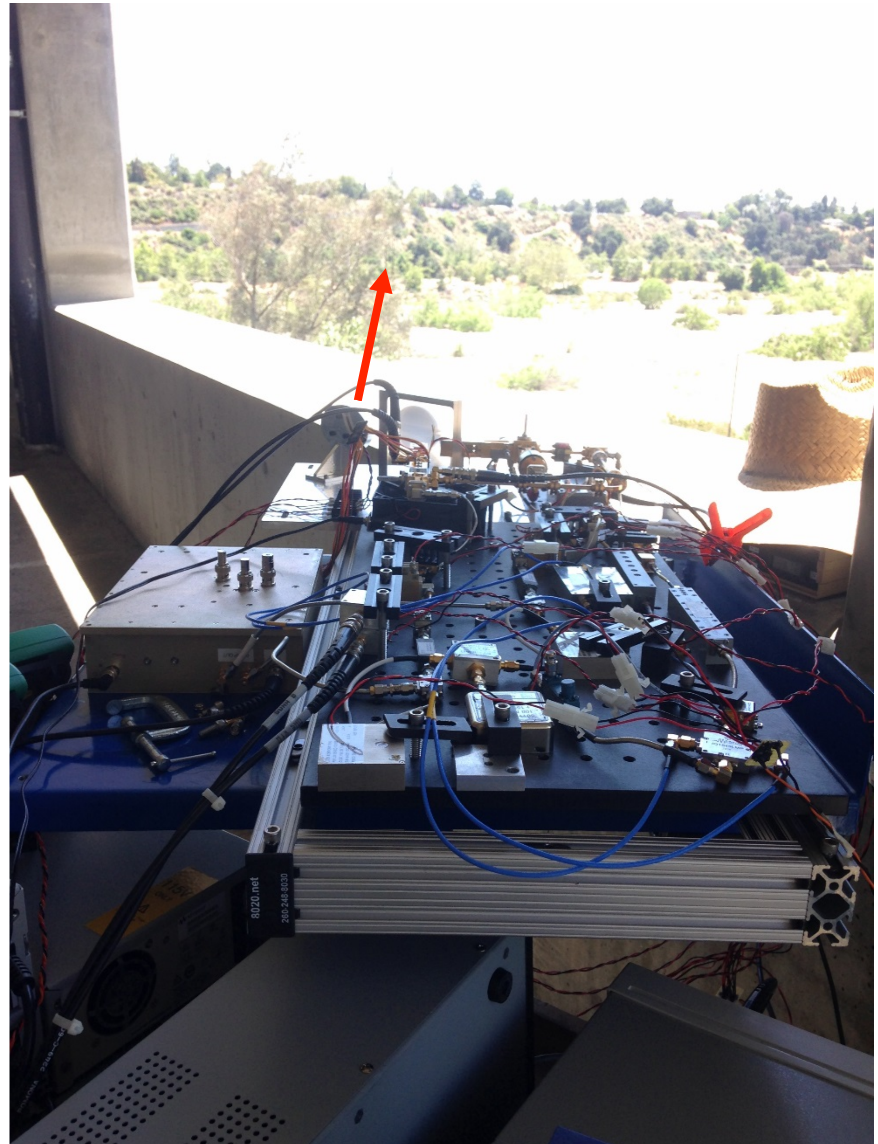




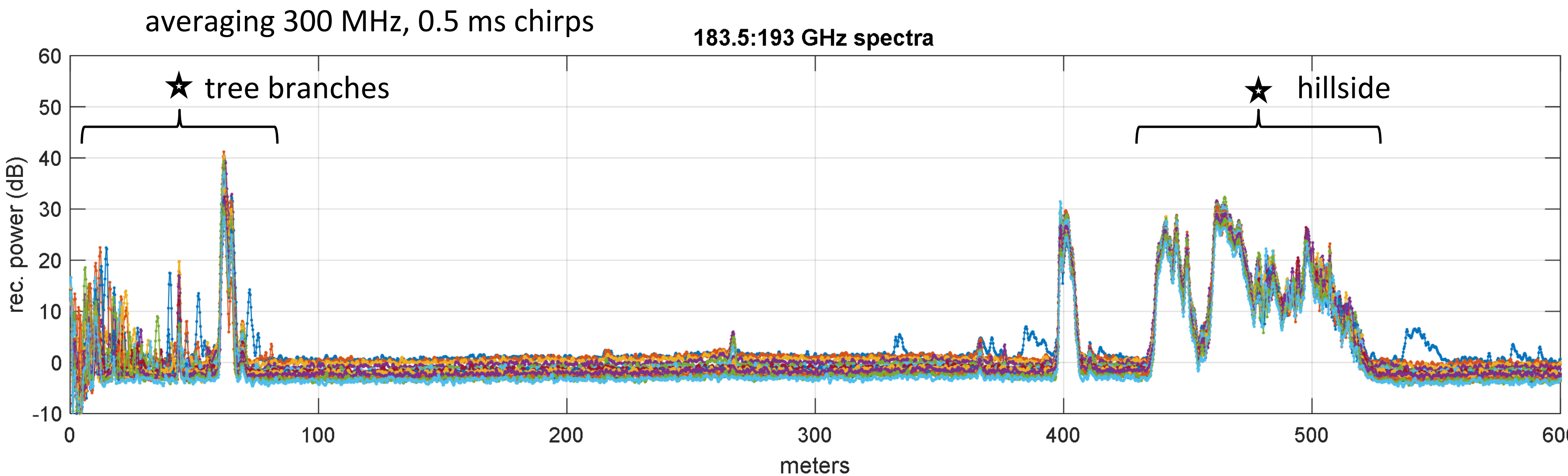
optics gain: 40 dB
receiver NF: 7 dB
detectable rain reflectivity at 300 m, 3 ms integration: -28 dBZ

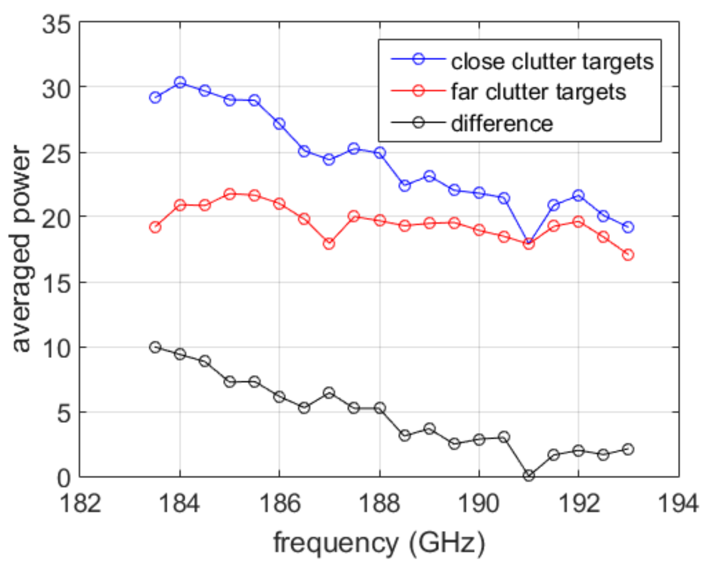
Tree & Hill Clutter Measurements

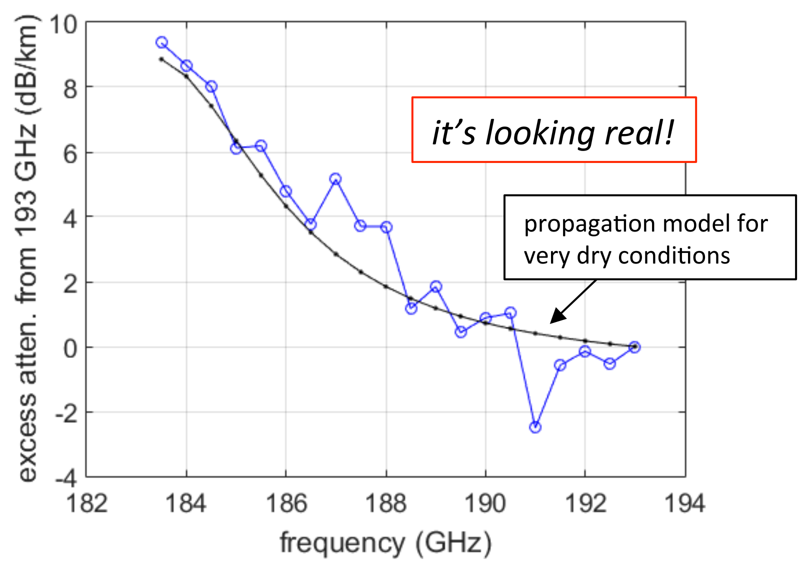




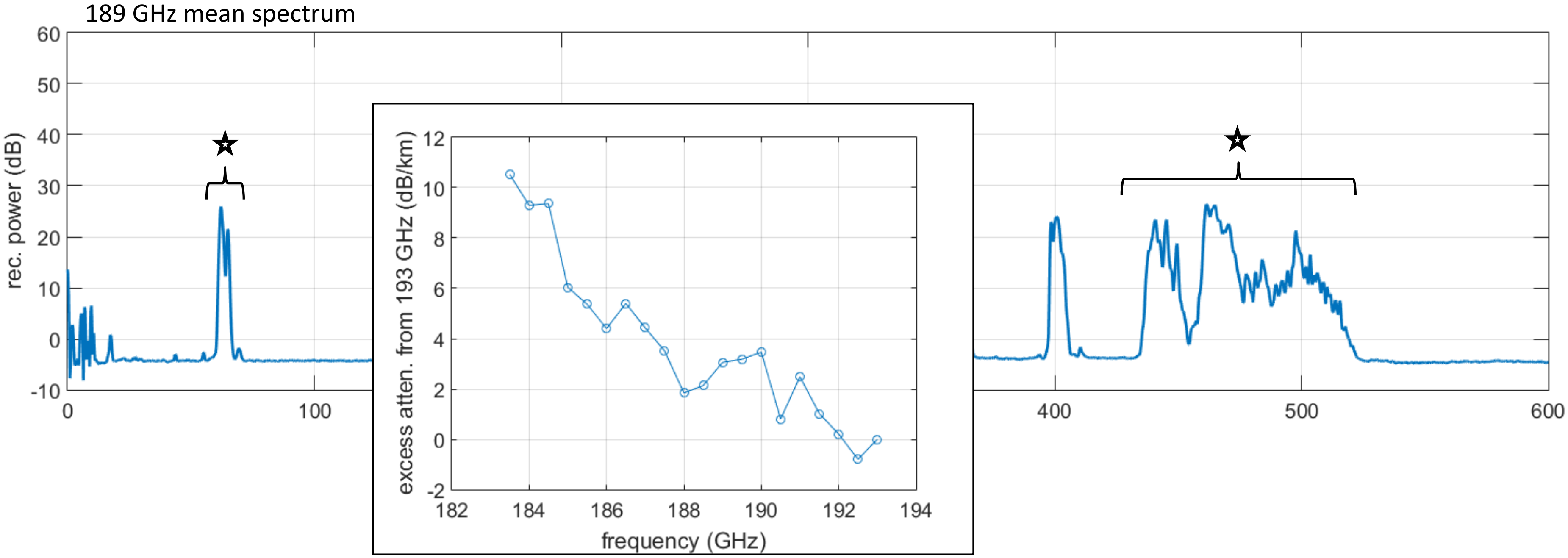
Measuring Humidity Using Clutter Targets

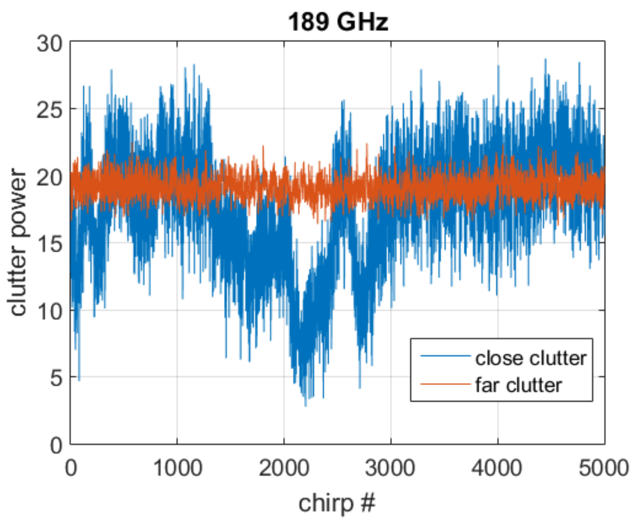


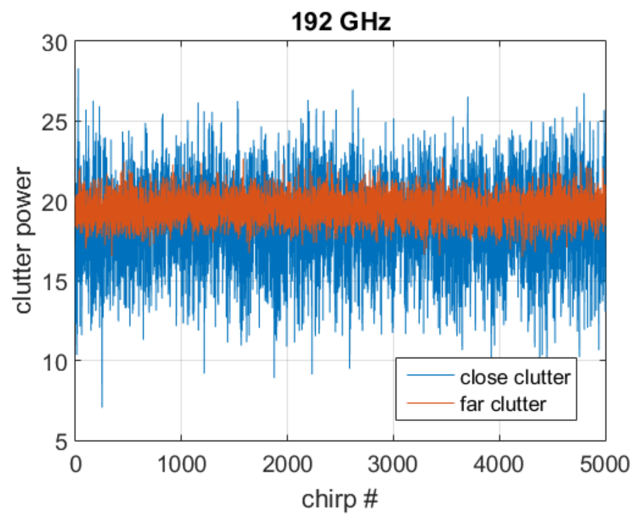




Clutter Target Statistics of Blowing Trees



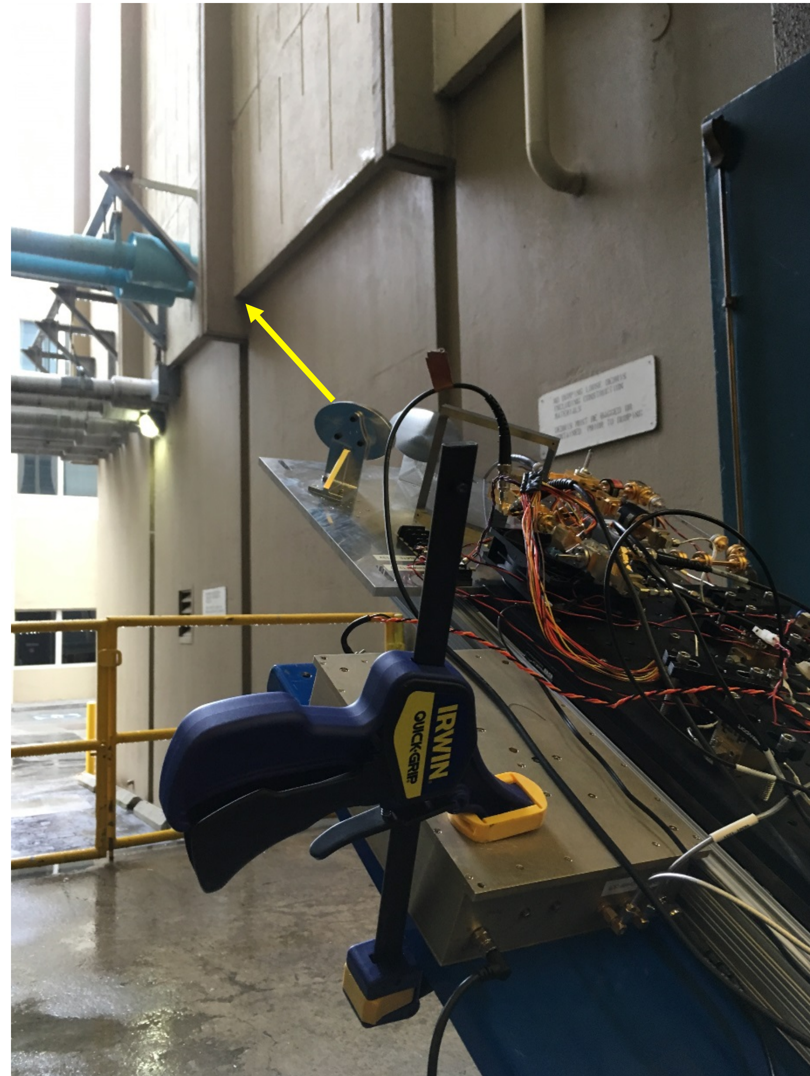




Frequencies are switched every ~30 seconds here.

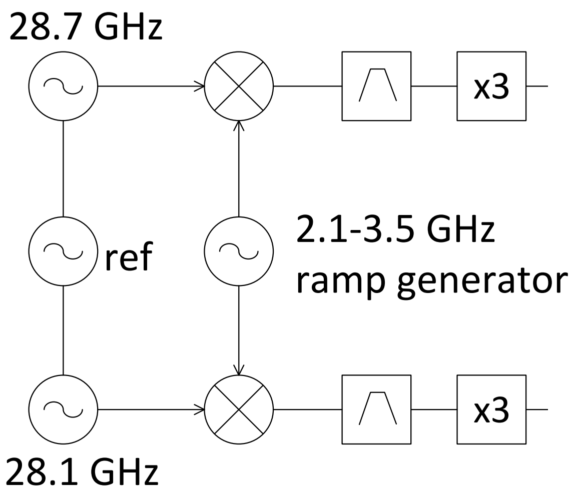
Dynamics of target brightness must vary more slowly than ~10 minutes for this approach to work.

Rain (or Clouds): An Excellent Clutter Target

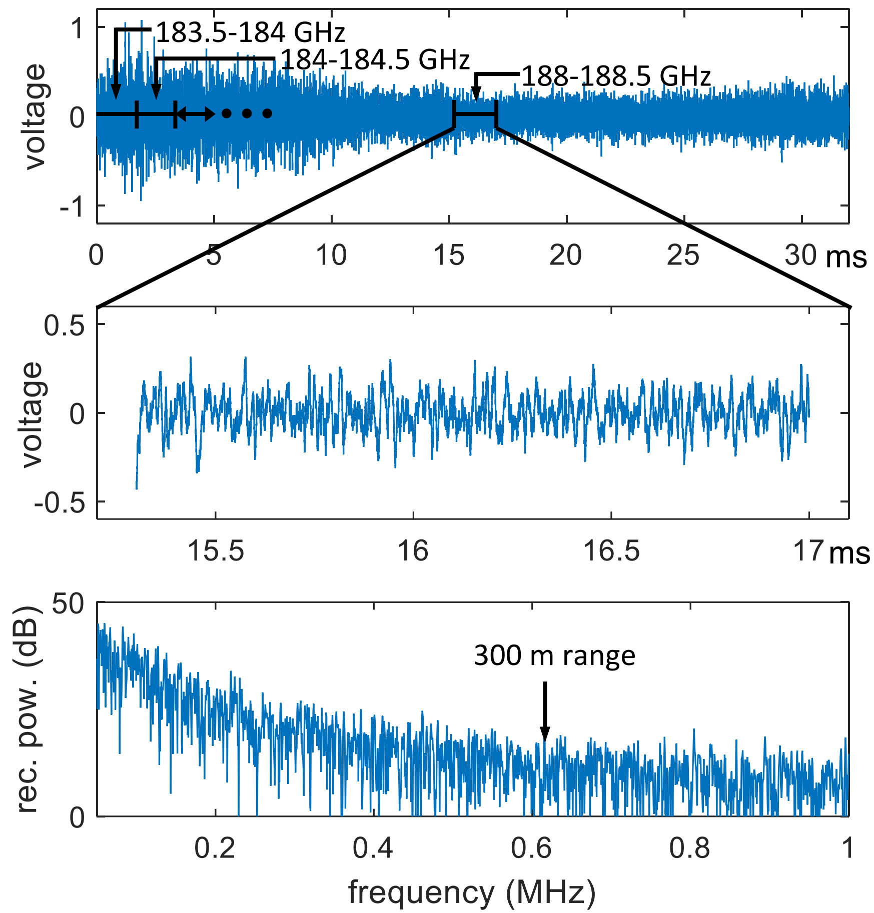


- No more problems with blowing corner reflector poles or tree branches
- No radiometer satellites were overhead: transmitting 183-193 GHz is sensitive.

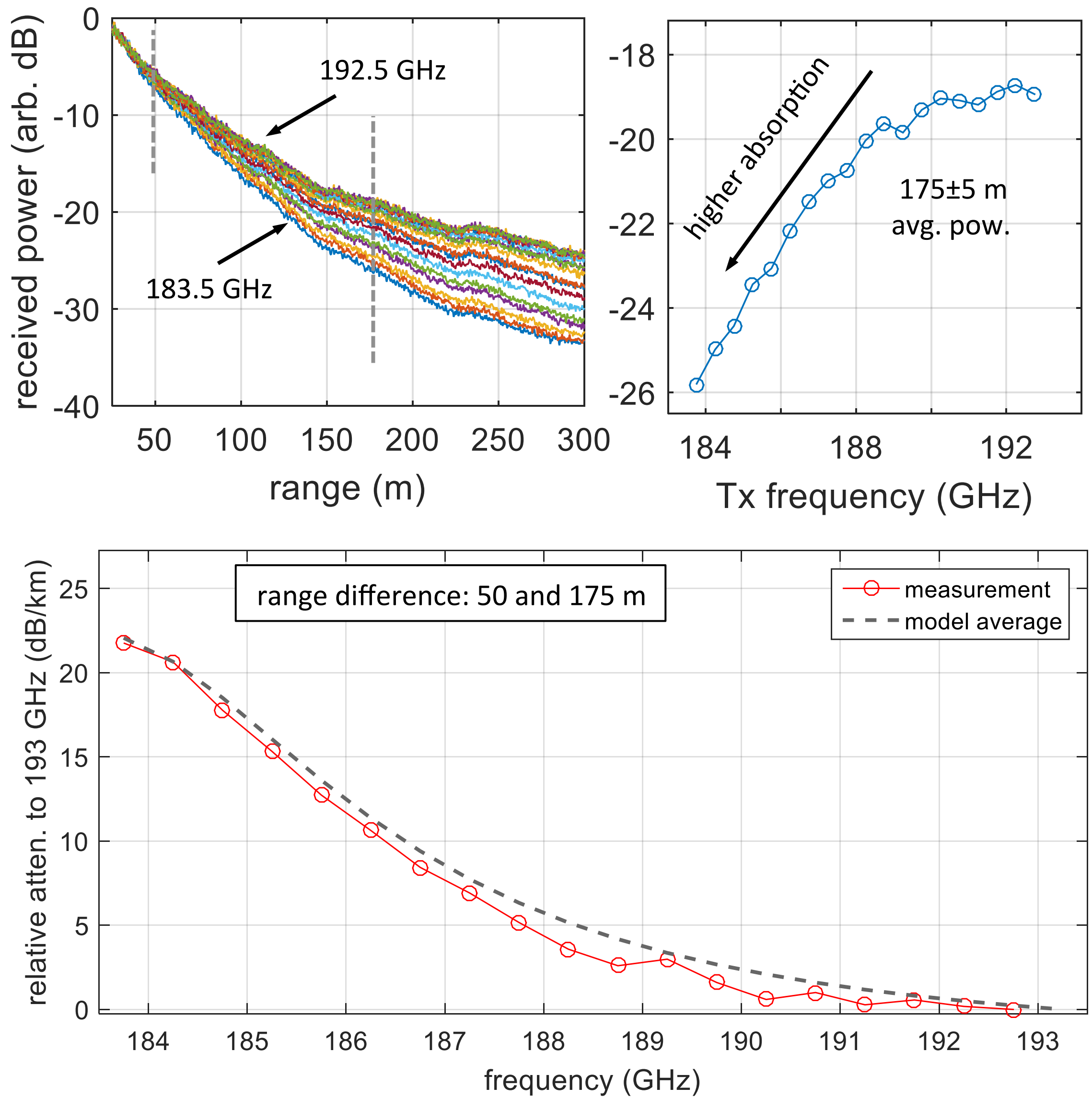
Crucial Technique: Fast Frequency "Switching"



- Perform entire 9.5 GHz chirp *at once* (in 32 ms) before the clutter target can decorrelate
- Acquire 500 total chirps in a row
- Calculate relative attenuations



Accurate Humidity Measurements Are Possible!



Conclusions

- New power-combining architectures are being developed for a 183 GHz differential absorption radar transceiver.
- 500 mW has been achieved, but for stable results new isolated-port power combining designs are now being fabricated and tested.
- Radar test-bench experiments show that differential absorption radar can effectively measure humidity inside rain. This is a new measurement technique!
- The measurements require fast frequency-switching when targets have potential for decorrelating.