# Antennas and Baselines

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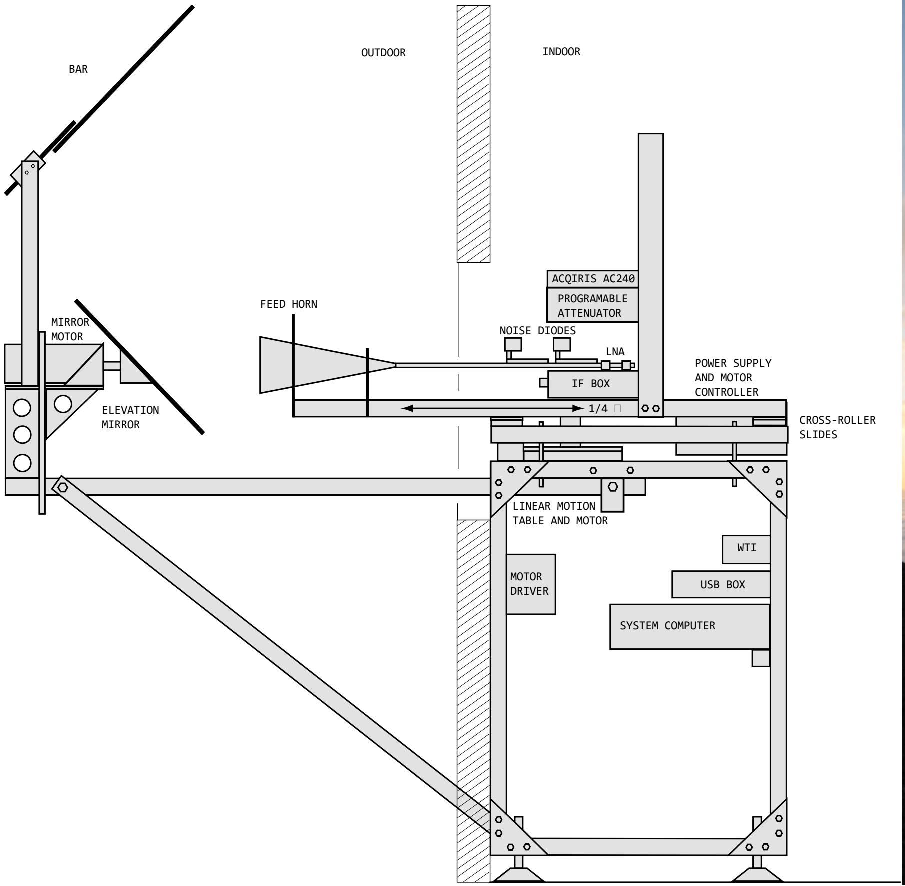
# The fourth generation Water Vapor Millimeter-wave Spectrometer (WVMS)

This is the fourth generation Water Vapor Millimeter-wave Spectrometer (WVMS) instrument. WVMS numbers are assigned in the order in which they were built. As mentioned before we now have four of these instruments in operation; WVMS 4, 5, 6, and 7.

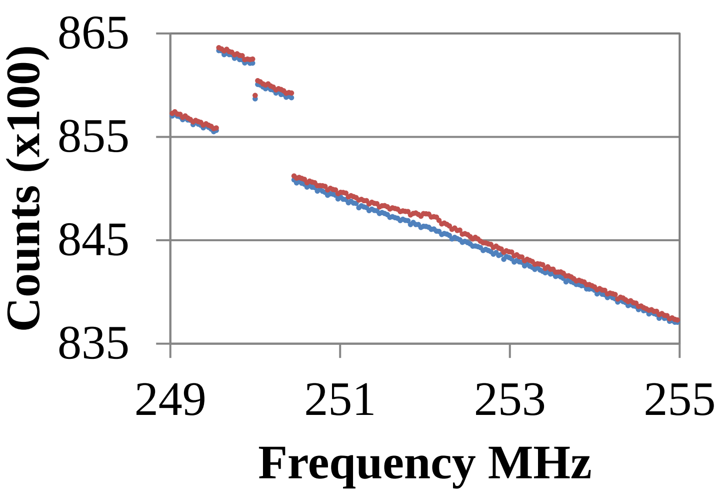




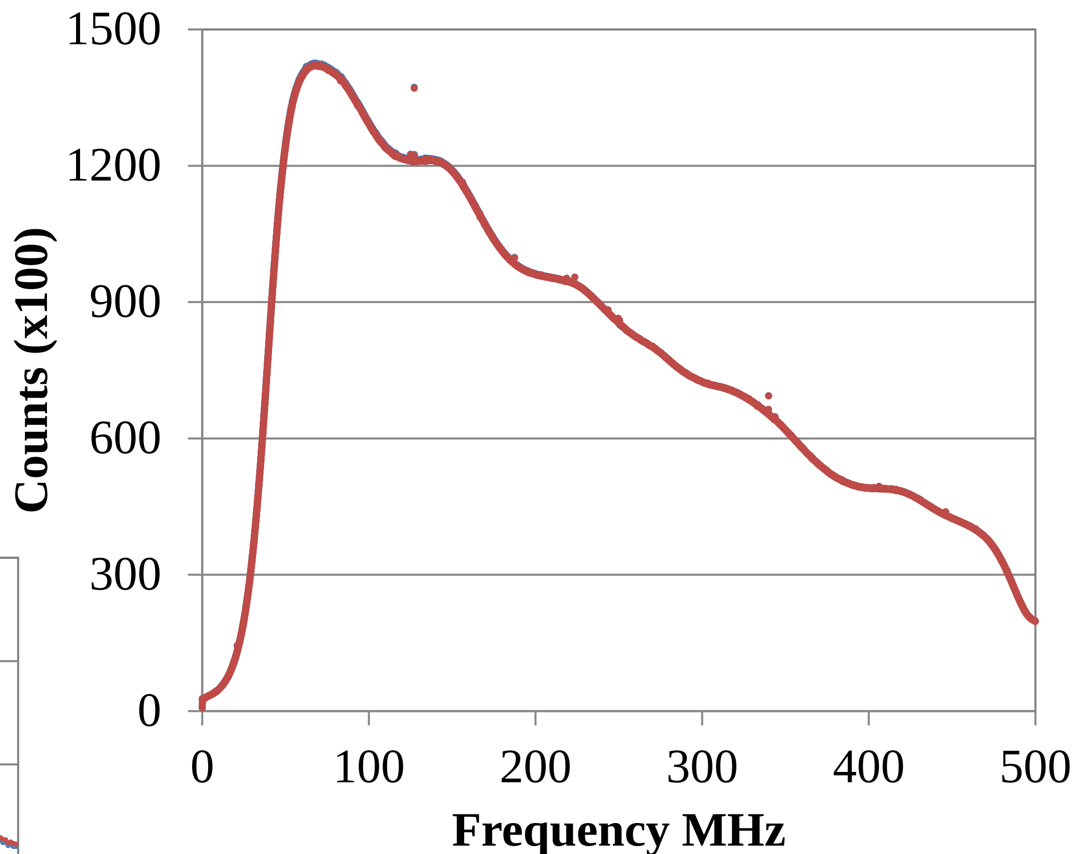
It uses the Agilent U1080A digitizer with FFT firmware to produce 16382 channels with a bandwidth of 500 MHz and a resolution of 31 KHz.

# Raw Signal Reference data from WVMS4

Full power measurements from signal and reference positions are shown in the plot.




The water vapor peak is apparent in the full power signal measurement.



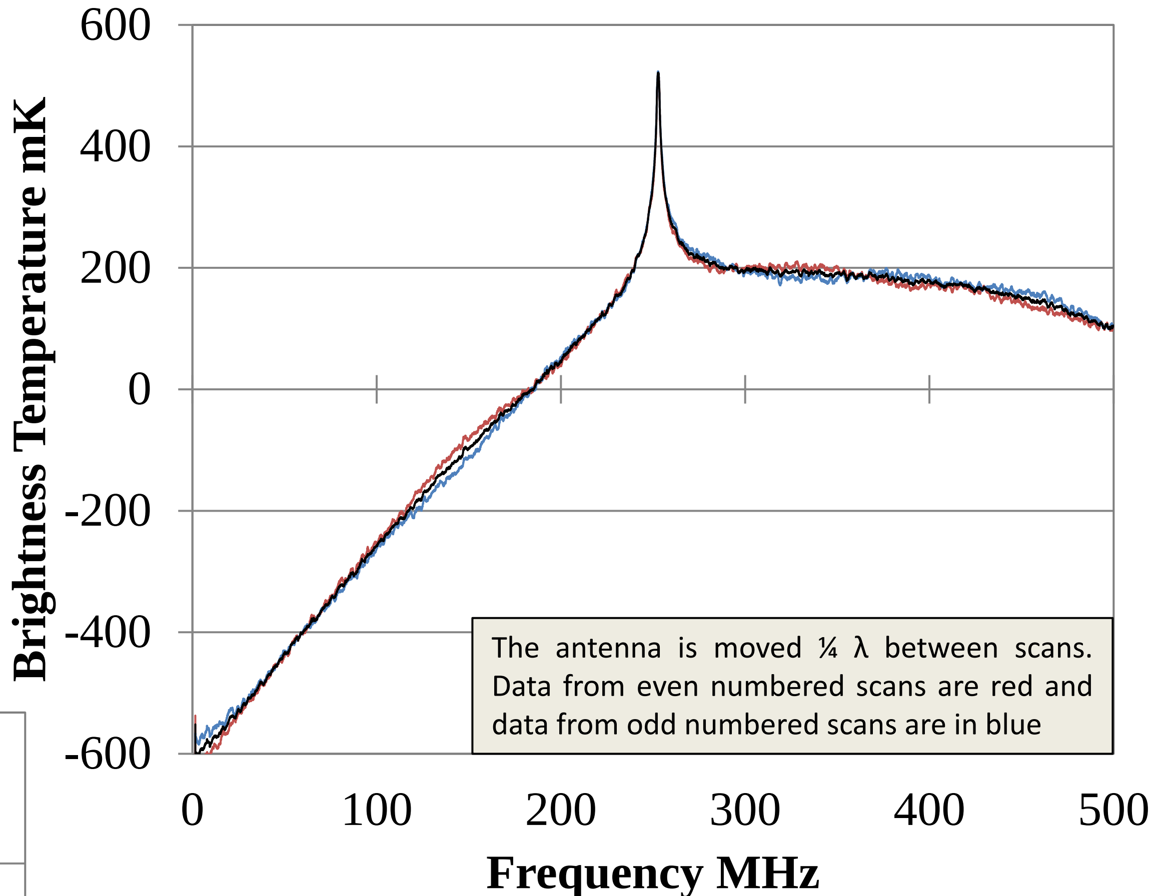

Data from the signal angle are in red and data from the reference angle are in blue

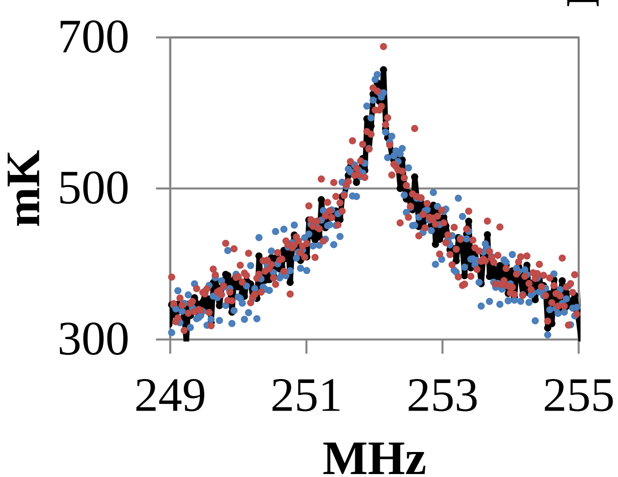
These measurements use two different fixed reference angles about 1 degree apart

# S – R from previous slide

The S-R water vapor spectrum is shown in the plot. The antenna is moved ¼ wavelength relative to the reflector after every 50 signal-reference pair. The red and blue line in the plot show the results from each of these two positions with the average in black. Where the red and blue lines separate there is a standing wave that is being cancelled out by the ¼ wave movement. It is this plot that we are going to use to examine baseline waves.

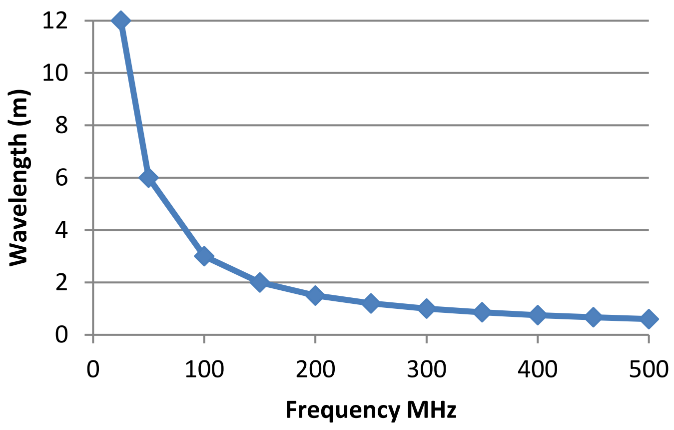
The plots on this page are of a 24 hour average. Some of the following plots are made in as little as 80 minutes so they will show more noise.




There are no baselines removed from this plot. All the following work is only possible because this instrument design has had the baselines reduced to this level.

## Sources of baseline waves




- Windows, covers
- Optics, reflectors
- Antennas and transitions
- Reference absorbers and plastics
- Cabling, connectors, impedance mismatches
- Amplifiers, mixers, and oscillators
- Mechanical, environmental, biological

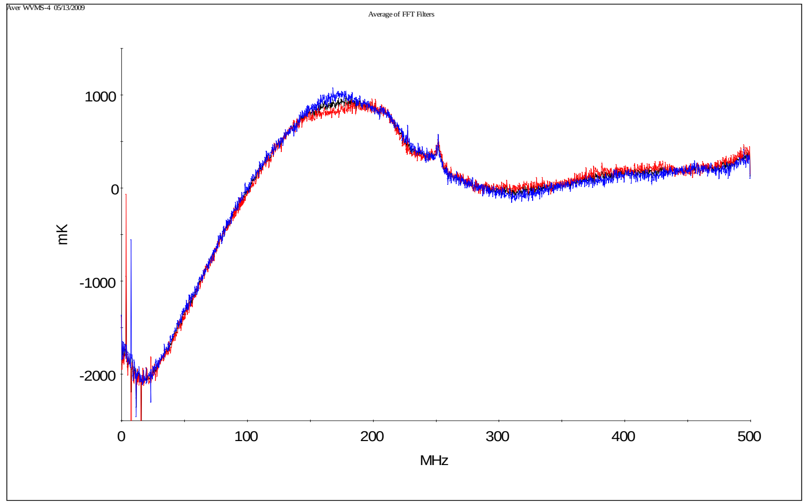
## Wave hunting

- Analyzing data to relate physical hardware to waves seen in the data
- Eliminate as many sources as possible and repeat

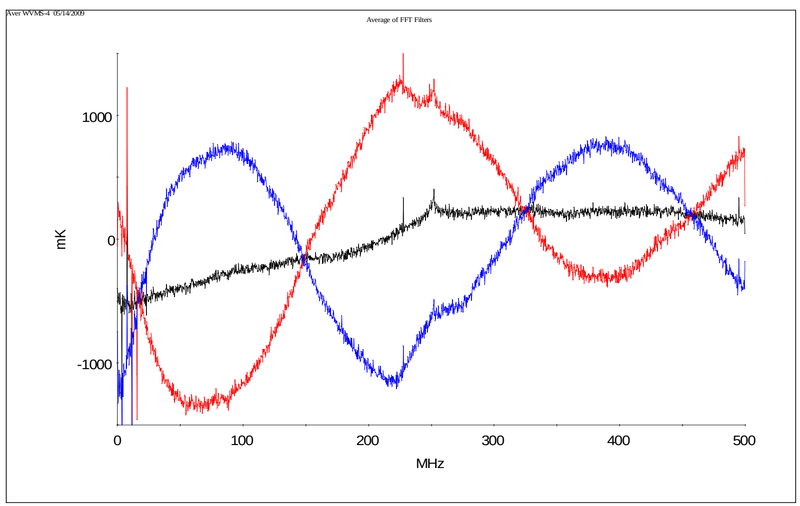
# Antenna cover in the reactive near field

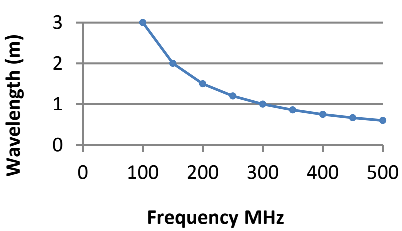
The antenna is moved ¼ λ between scans. Data from even numbered scans are red and data from odd numbered scans are in blue

Here we test a composite radome material manufactured for me by MFG Galileo Composites. It is fixed to the front of the antenna and moves with it. It is supposed to be transparent at 22 GHz however there is a clear 300 MHz wave caused by a reflection from the front to the back of the ½ meter antenna.



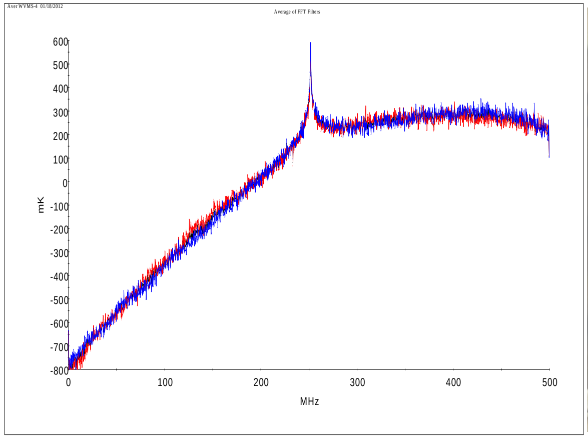

Here we see the same cover set up so that the antenna moves ¼ λ relative to the material. The 300 MHz wave caused by the cover is canceled by the ¼ λ = 3.373 mm movement.

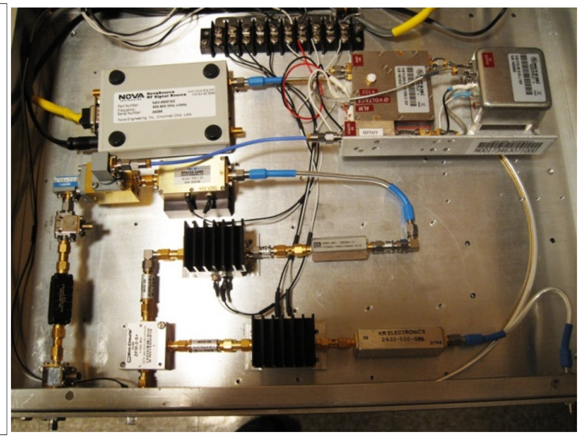


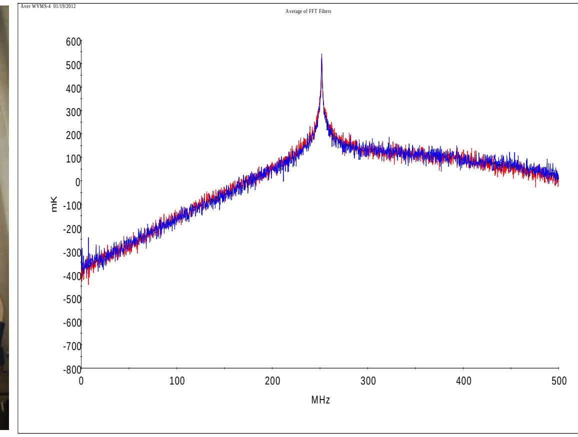



# Baseline Wave Hunting

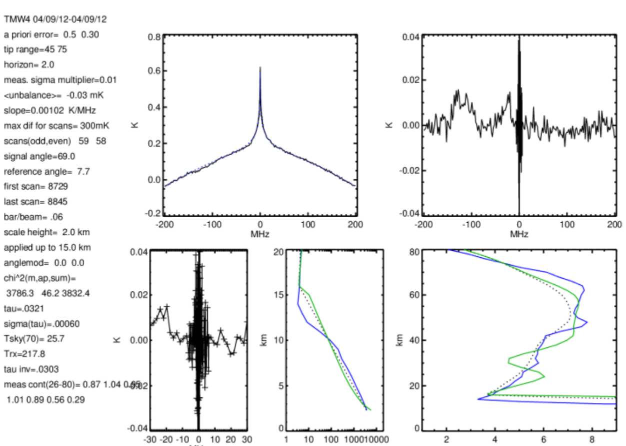
## First order wave hunting: Relating waves in the spectrum to hardware (hours)

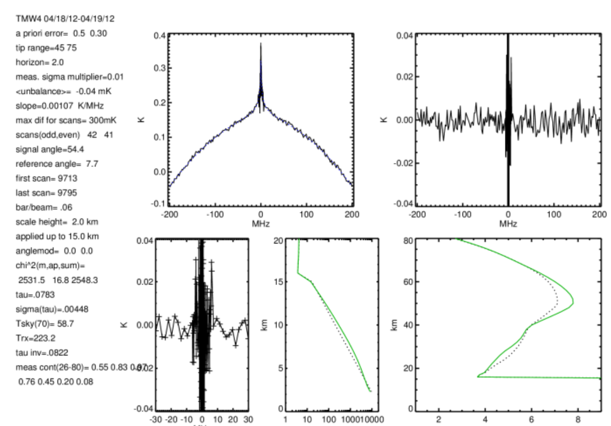


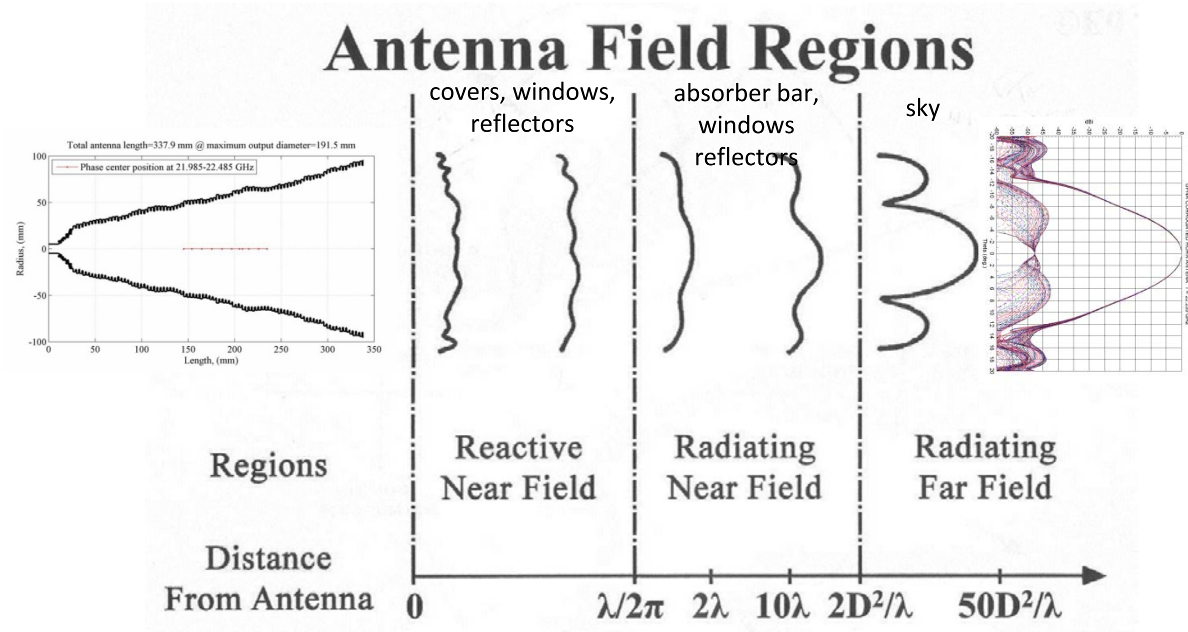




## Second order wave hunting: Relating waves in the retrieval residual to hardware (days)

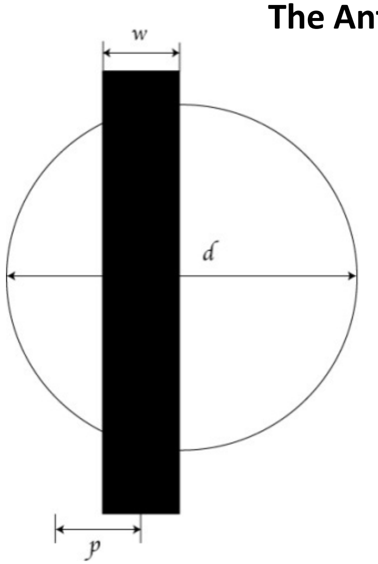


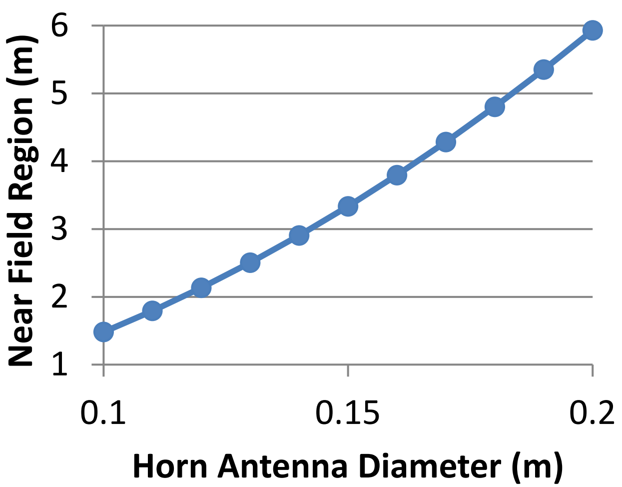



# The problem with Dicke Switching using absorber in only part of the beam



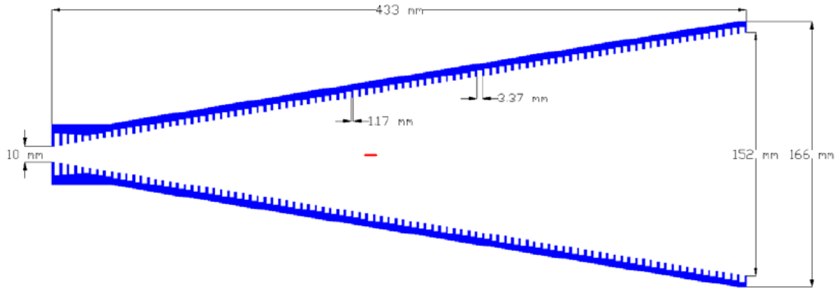

**The Antenna Pattern is only Present in the Radiating Far-Field Region**

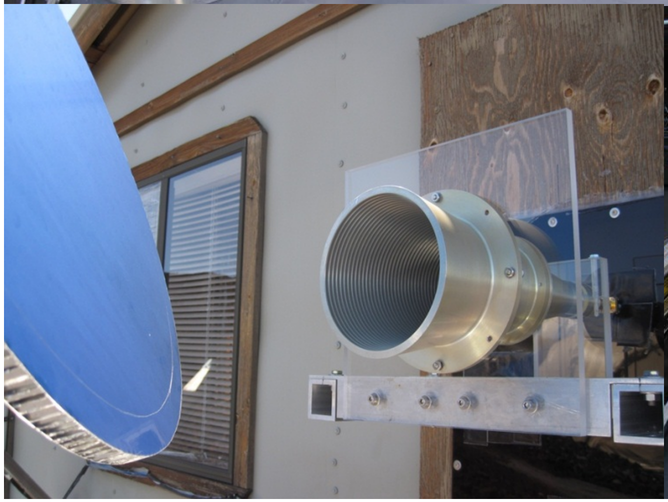


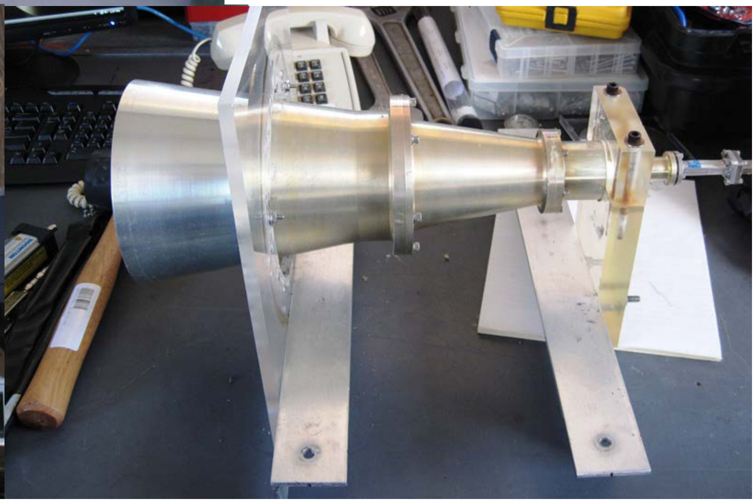



# NRL Antenna
# 22.235 GHz   λ=13.49224 mm
# D = 152 mm  Near Field = 3.4 m

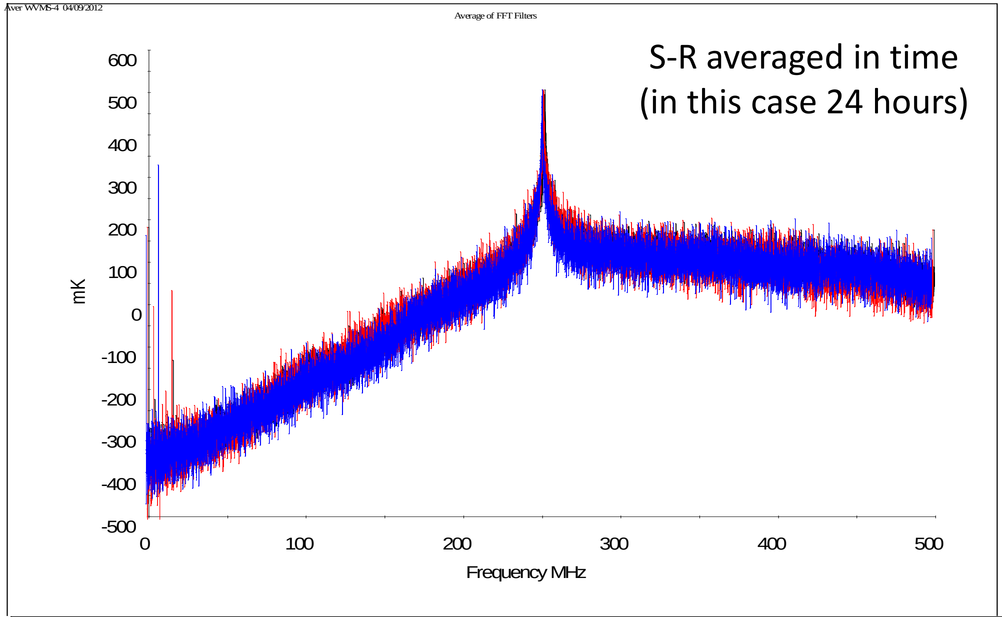
This is our main antenna. It is scaled up (early 80's) from a smaller JPL design (late 70's). We have an inventory of 4 of these antennas and they were manually manufactured in five segments. They have around 25 dB of gain and a FWHM of approximately 8 degrees.

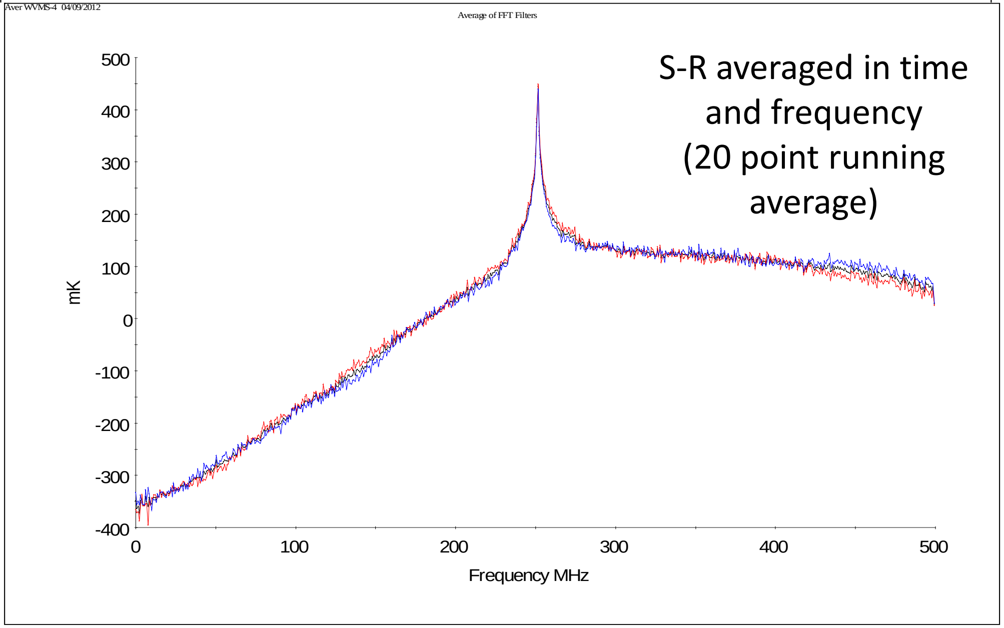




# Current Measurements Using WVMS4 antenna 1

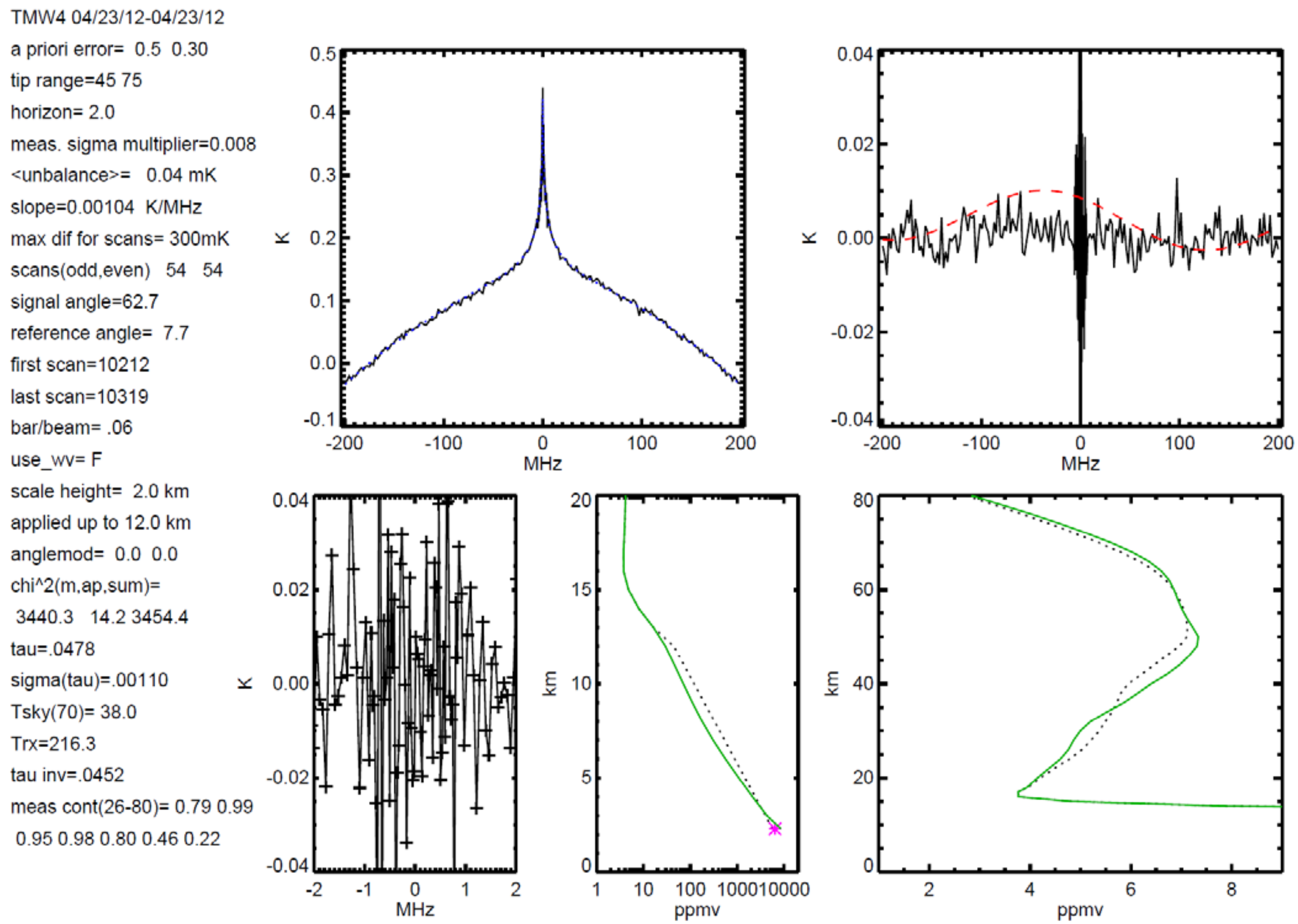



This is the current WVMS4 instrument at table mountain with the bar at two meters. You will notice the shape and slope varies little from the previous plot. We will call this antenna 1. It is important to note here the shape and slope of this spectrum as we compare this to the following plots.

# WVMS4 Retrieval

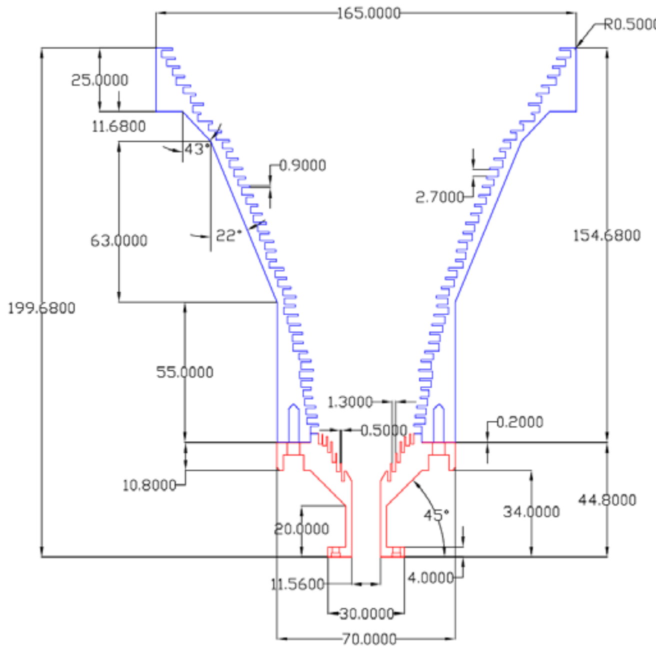
This is a standard WVMS4 retrieval. The red line is a single baseline fit.



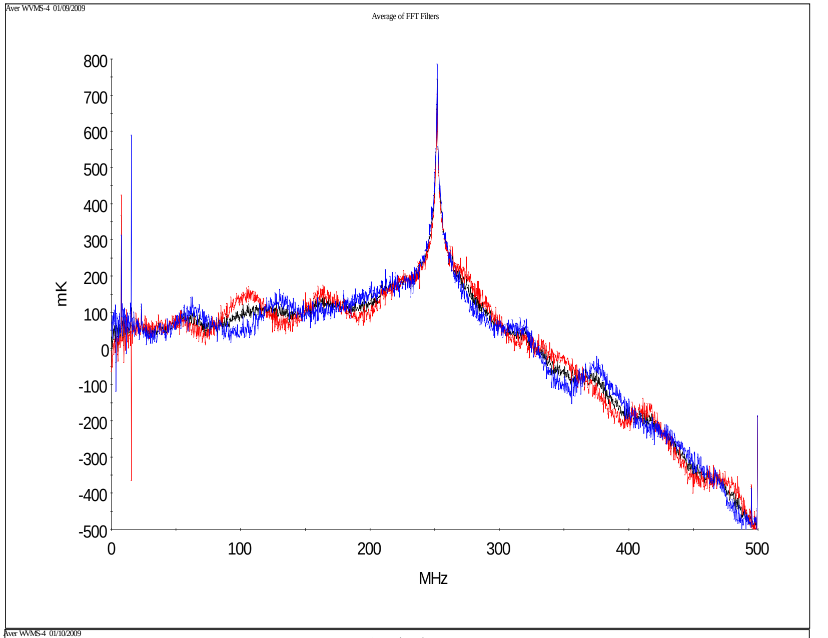
Measurements Using Public University of Navarra (UPNA) FzK design antenna

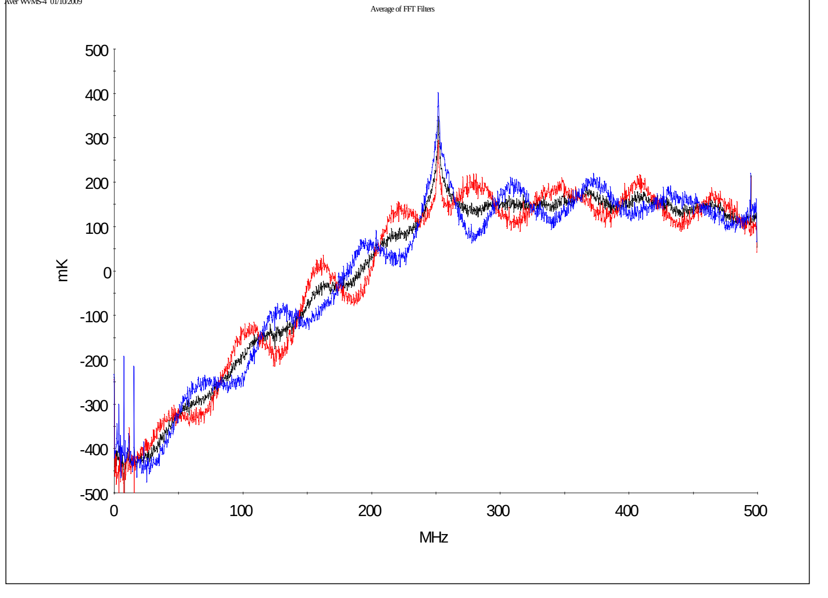
D = 165 mm   Near Field = 4 m

FWHM 12 degrees




# FzK horn on WVMS4



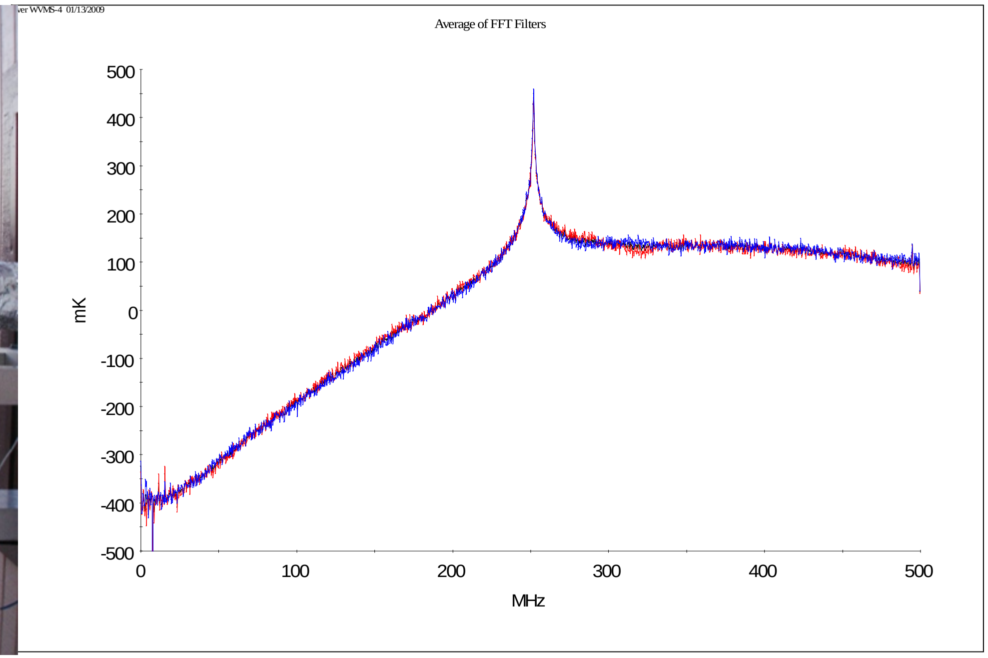




This is an eighteen hour averaged spectra from WVMS4 with the FzK design horn borrowed from Giovanni. The initial spectrum slopes in the wrong direction.

The reference angle was changed placing less of the bar in the beam and the slope was corrected.

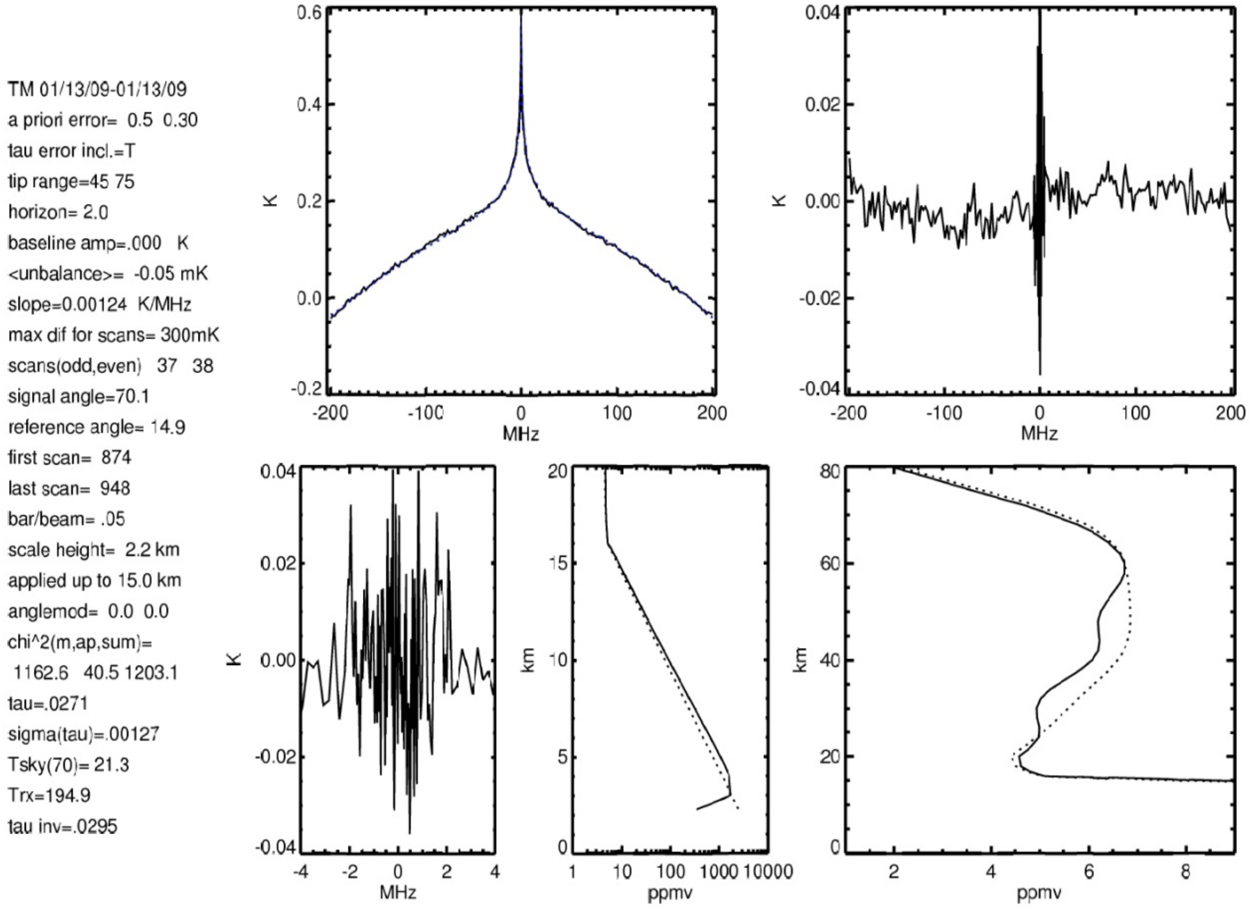
# The absorber box solution

## We now have a spectrum good enough to retrieve



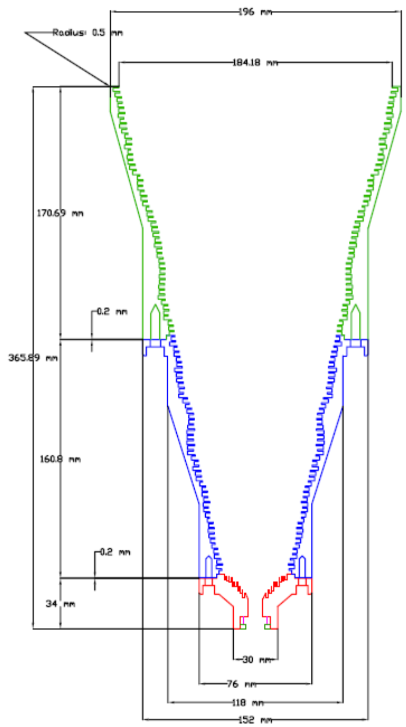

This is a daily averaged spectra from WVMS4 with the FzK design antenna. 60x60 cm sheets of absorber were added to the viewing area to remove standing waves.

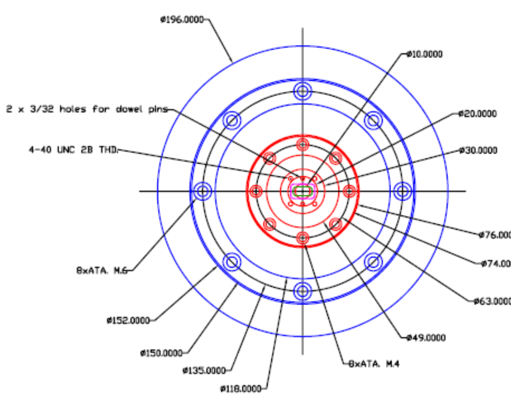
# WVMS 4 with FzK antenna

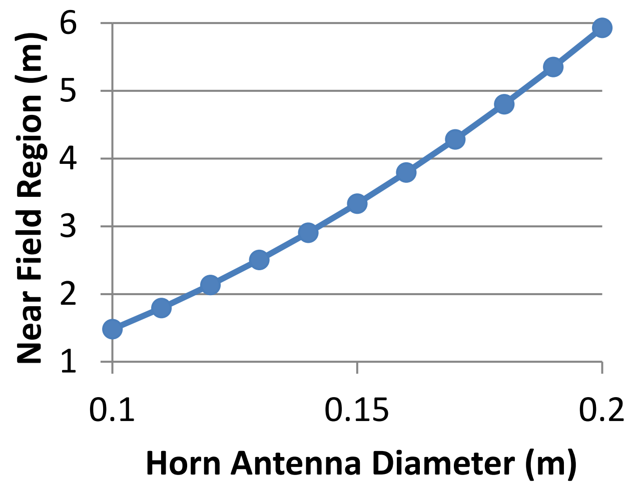


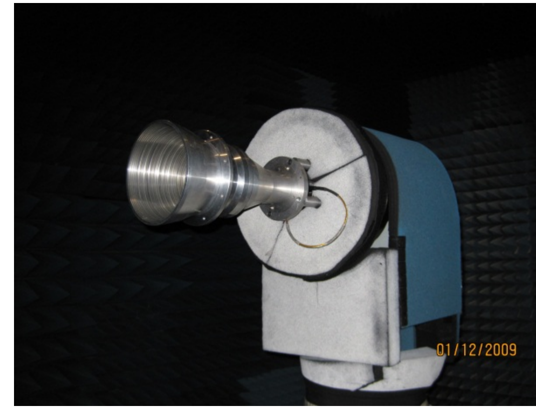

This is a retrieval of on a daily averaged spectra from WVMS4 with the FzK design antenna. The profile looks reasonable and the residuals have very few artifacts.

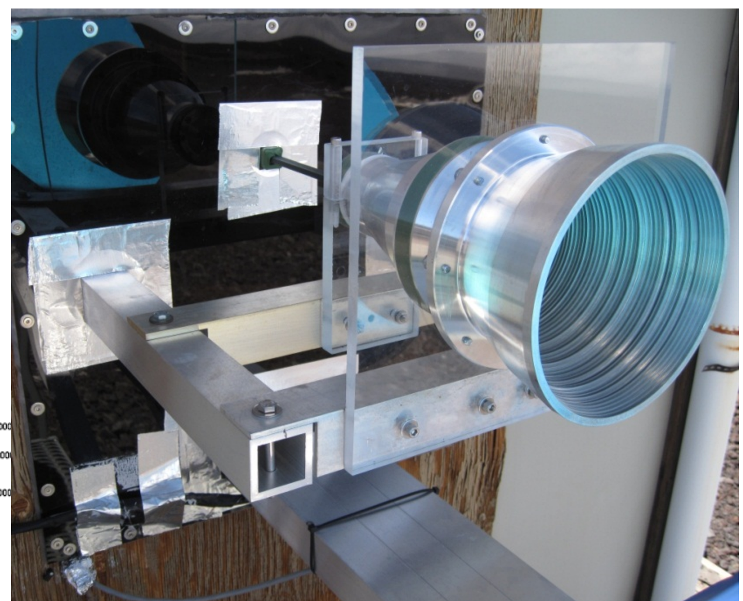
# Measurements Using New UPNA NRL Design antenna
# D = 184 mm    Near Field = 5 m
# FWHM 6 degrees



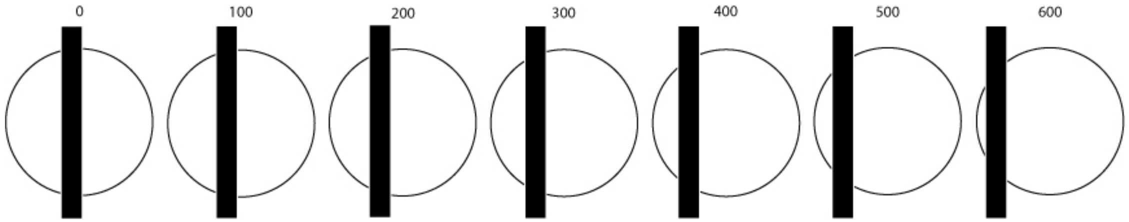



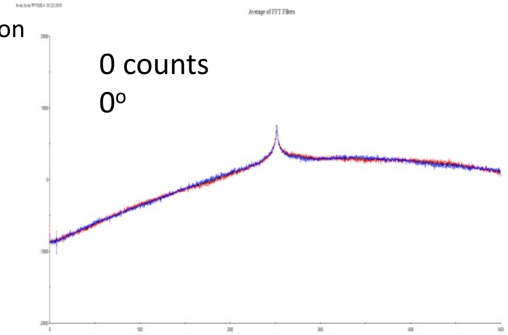



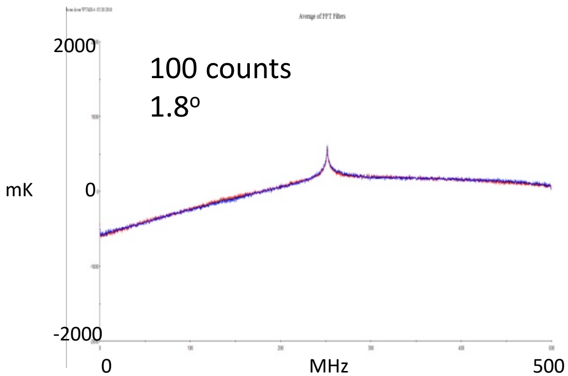



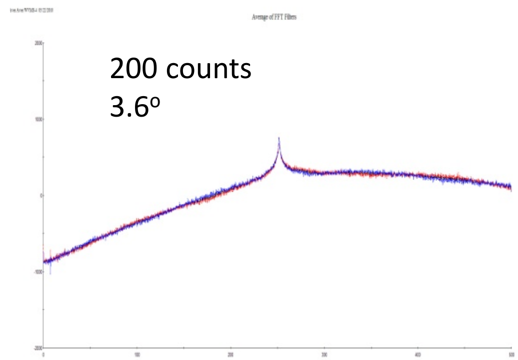
# Changing reference angles with Antenna 1

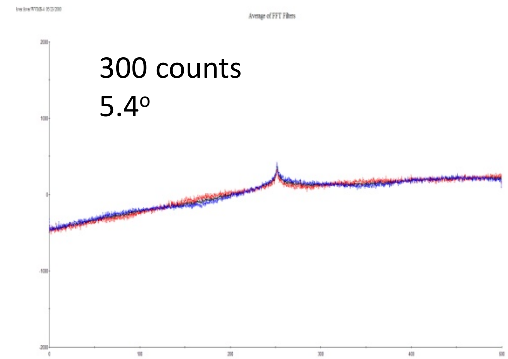
The circles represent the beam and the vertical bar represents the absorber material in the reference position

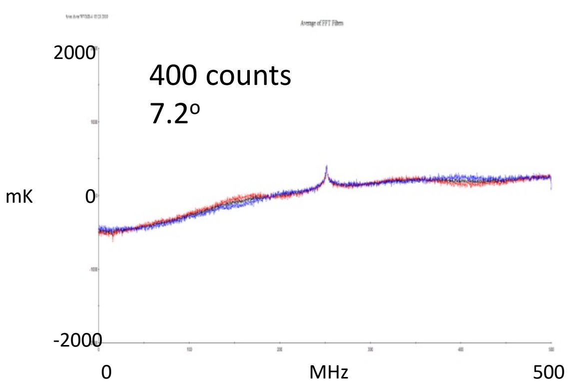


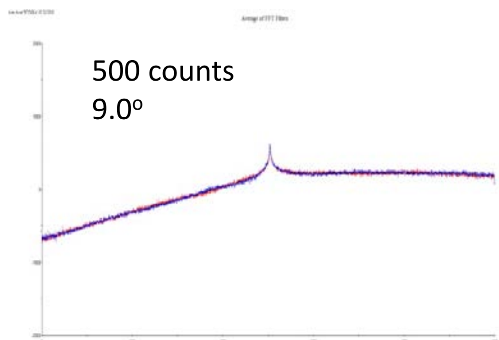



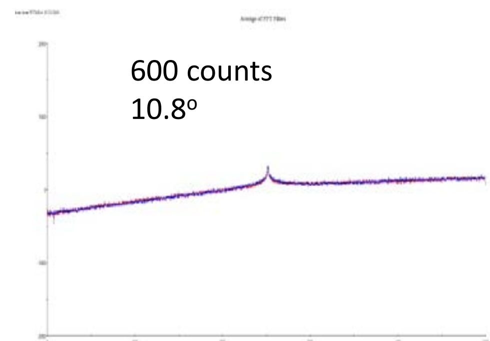



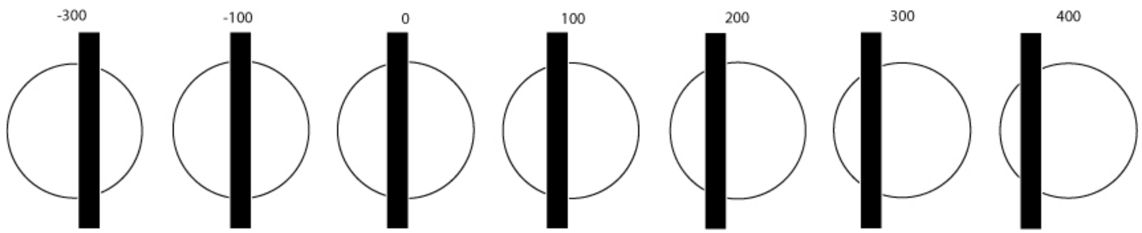



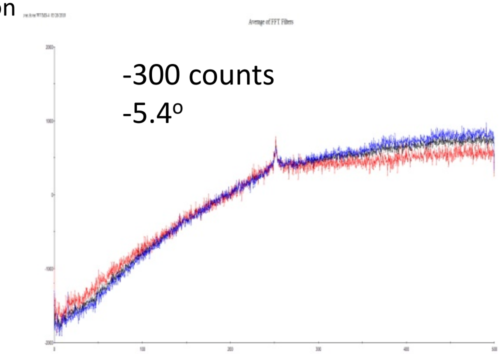



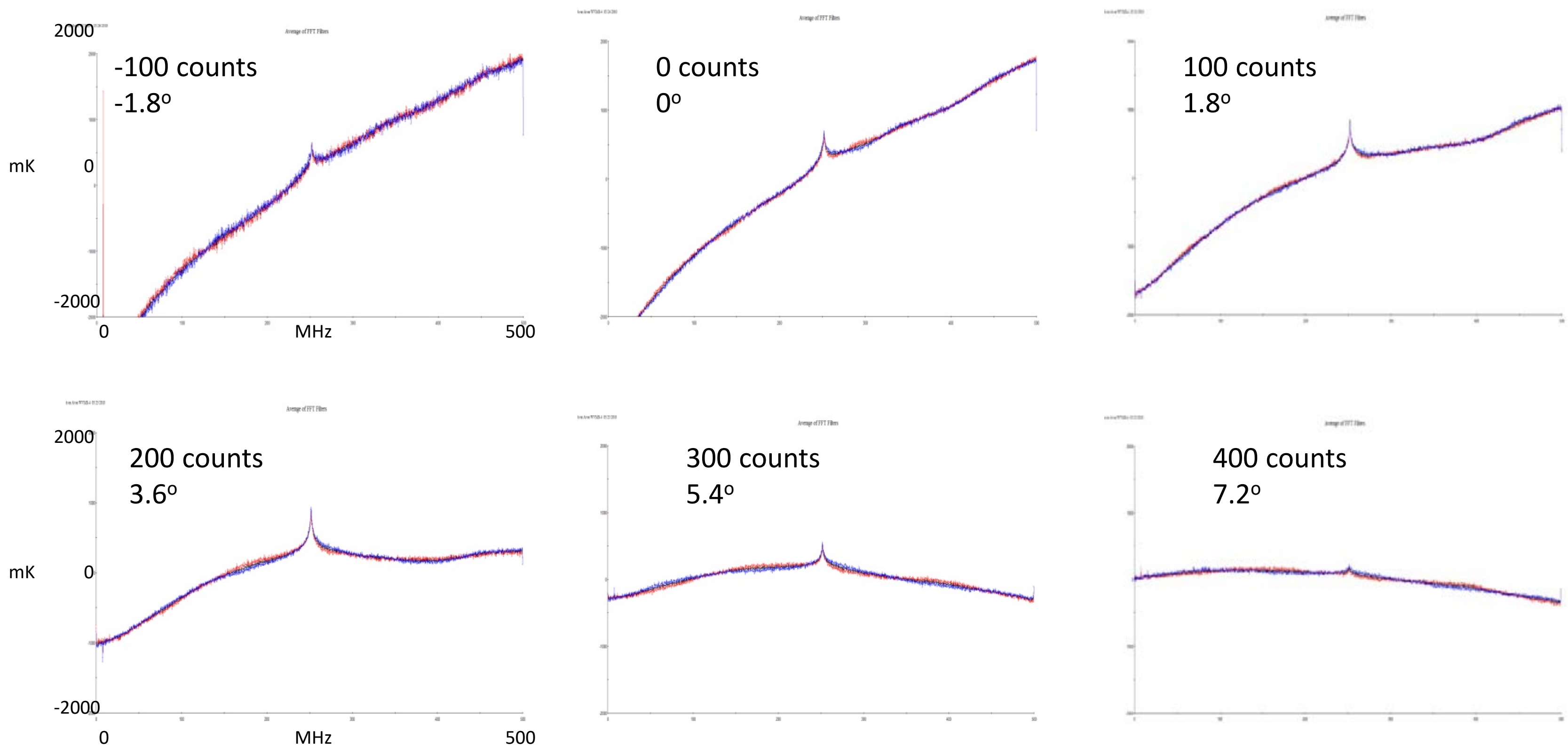



# Changing reference angles with the new UPNA NRL antenna

The circles represent the beam and the vertical bar represents the absorber material in the reference position



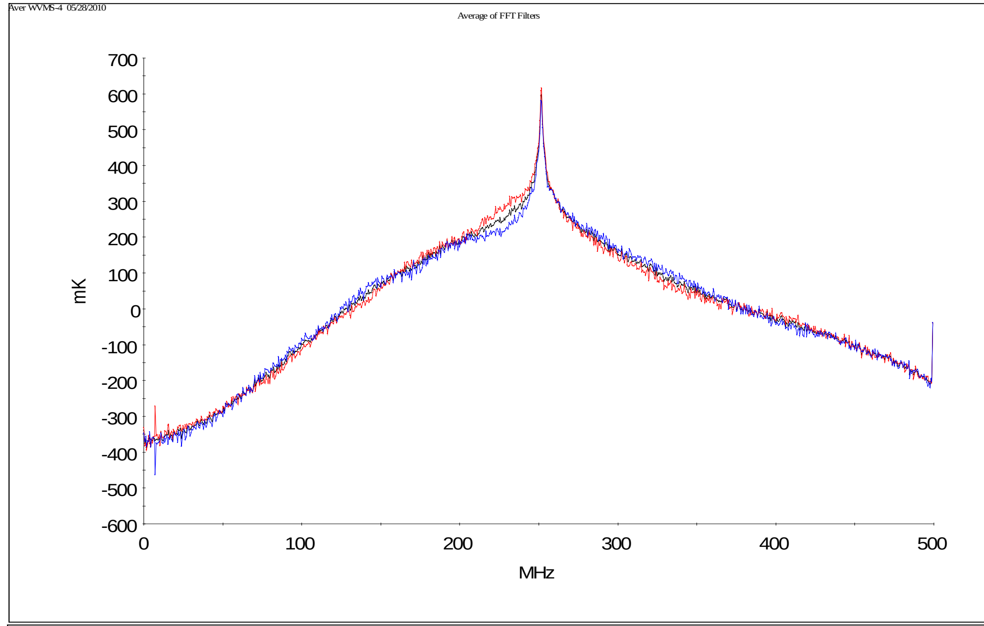



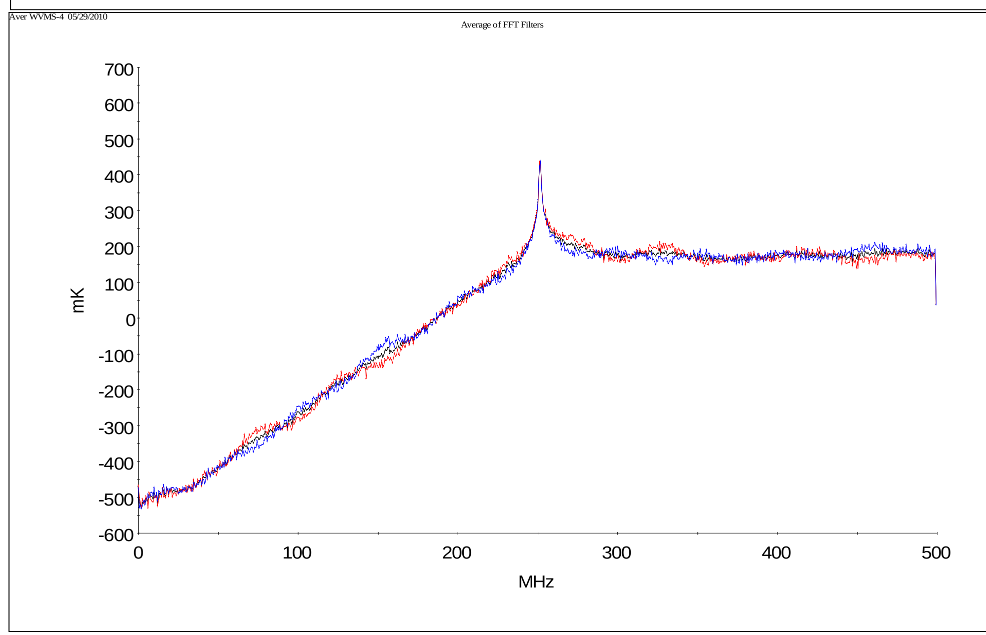



Different absorber materials have little bearing on this problem


Although there are some differences between absorber materials used their differences have little impact on baseline problems. However how you use them matters.

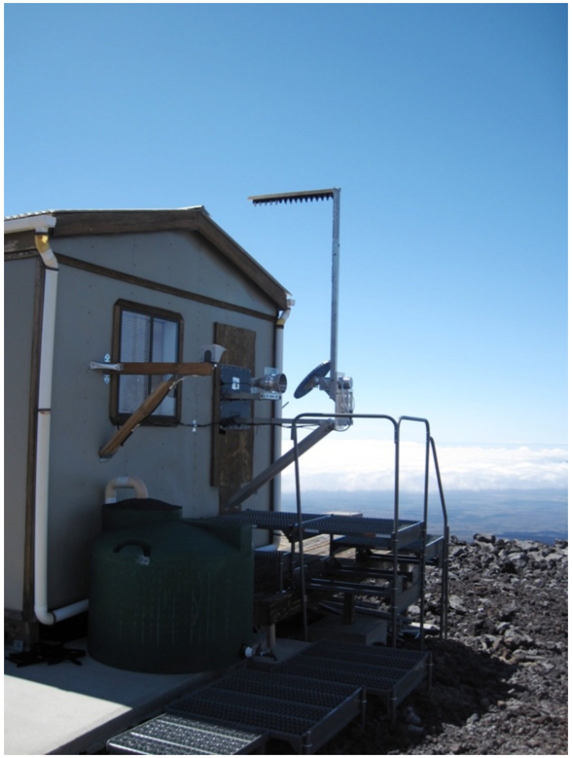
# Flat Bar vs. Angled Bar

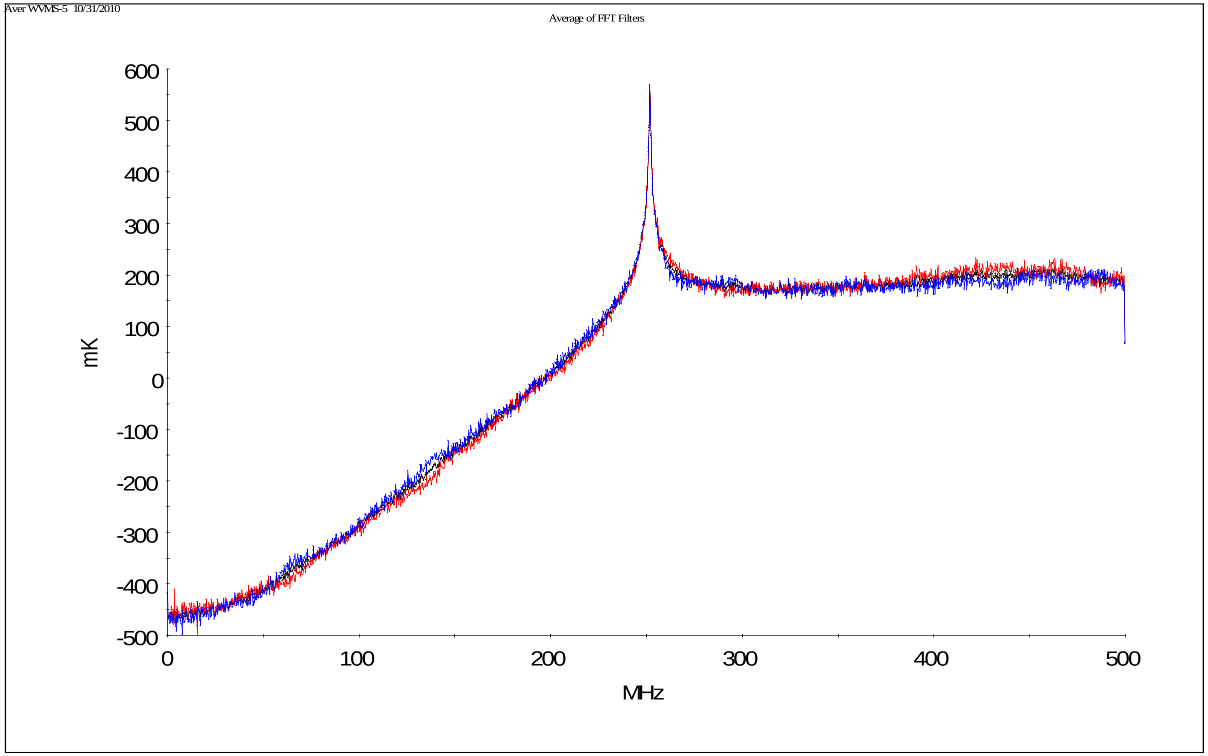


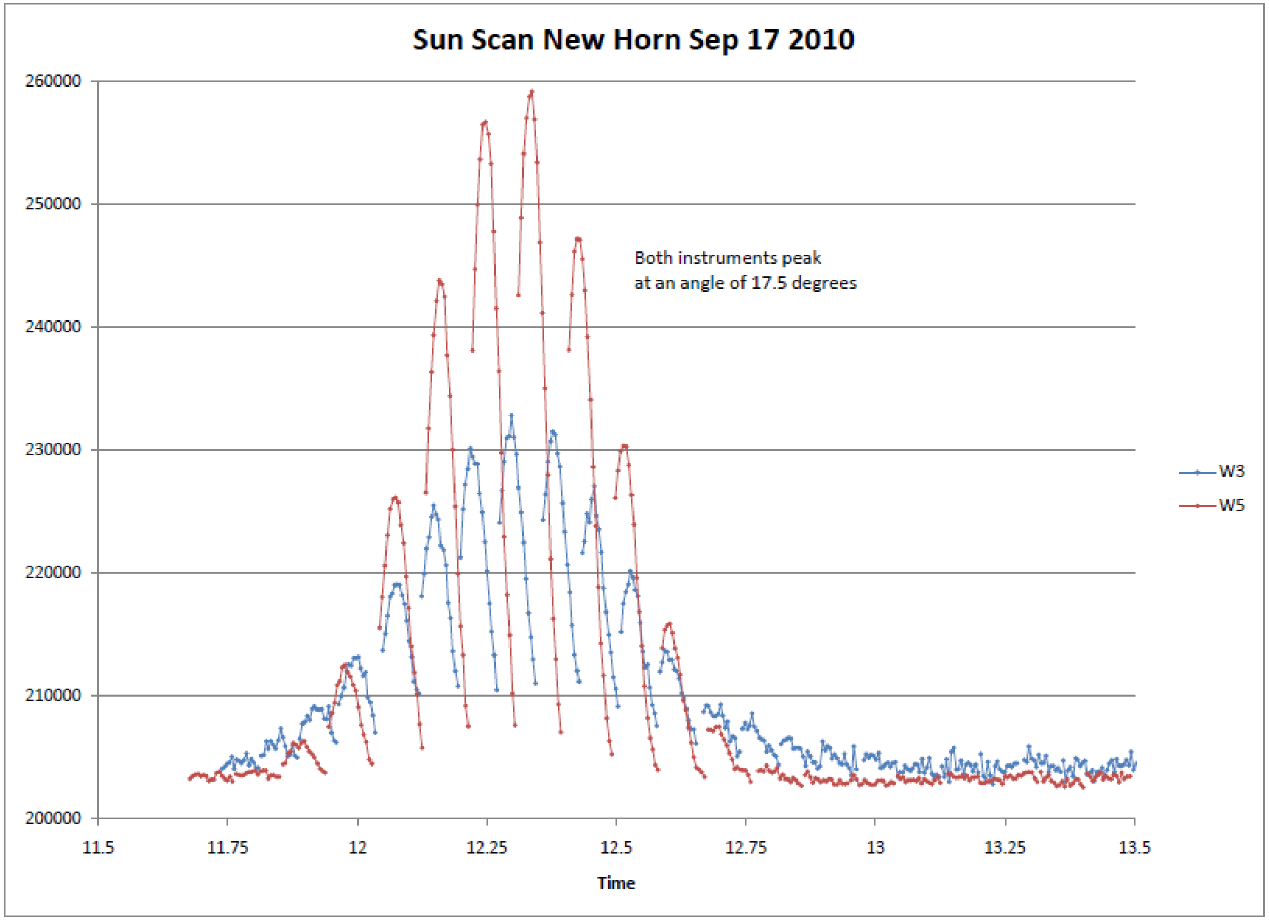
# First order wave hunting: Comparing the UPNA NRL antenna on WVMS5 at Mauna Loa

The same antenna was then taken to Mauna Loa in Hawaii and tested on WVMS5. Here we have the opportunity to test the horn at a high altitude sight and compare not only antennas on the same instrument but simultaneous measurements made with WVMS3. We now have a  good enough spectrum to retrieve.



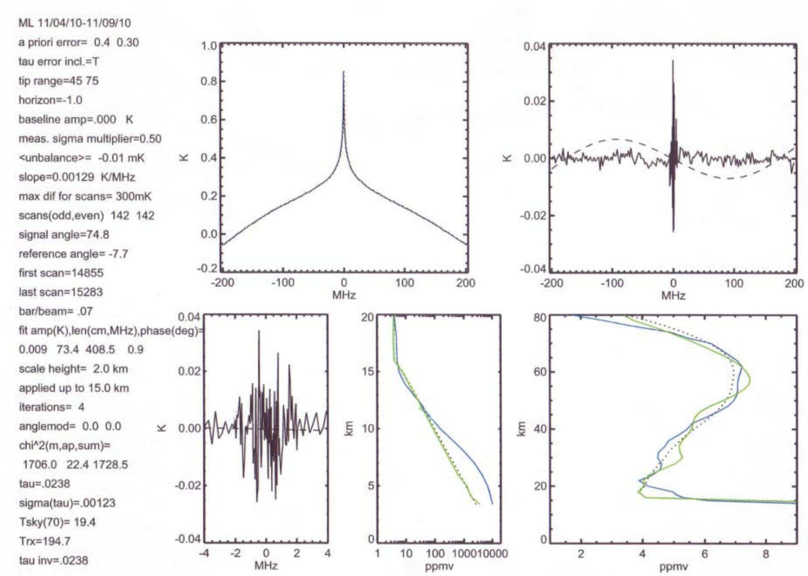


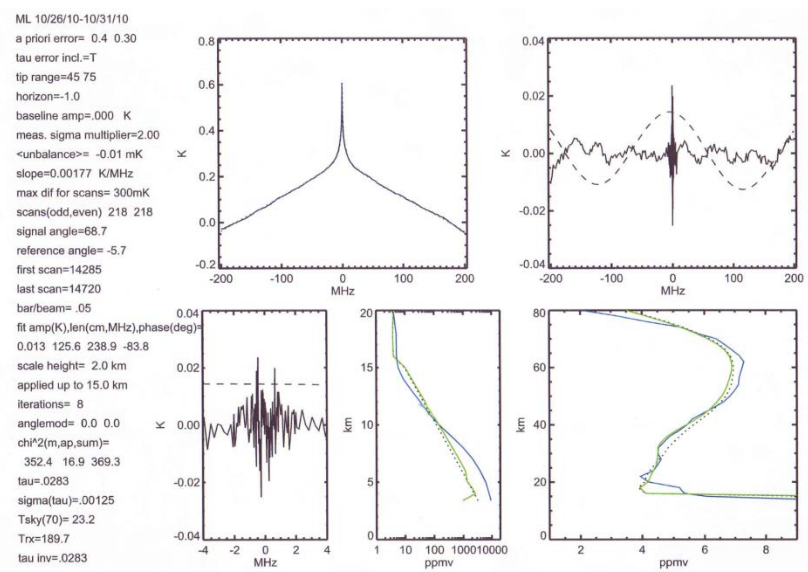

This plot is of WVMS3 and WVMS5 instruments scanning through the sun as it passes by. The Y scale is in mK (times 1000) and the X scale is of course in local Hawaiian Pacific time. It is interesting to note that the antenna with the 8 degree beam on WVMS3 can see the sun a little longer than the antenna with the 6 degree beam on WVMS5.



# Second order wave hunting : WVMS5 retrievals with both antennas

Although the spectra looks Reasonable there is still a wave pattern that can be attributed to the UPNA NRL antenna that does not appear in the other antennas in our inventory. Mitigation of this wave causes problems in the water vapor retrieval. The hardware solution would probably involve moving the bar beyond 2 meters.

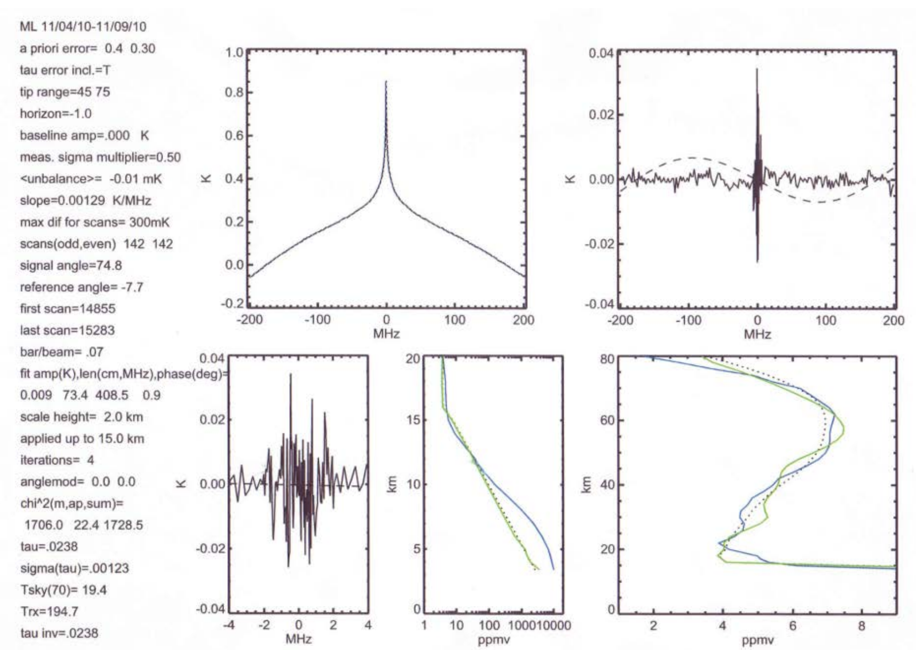


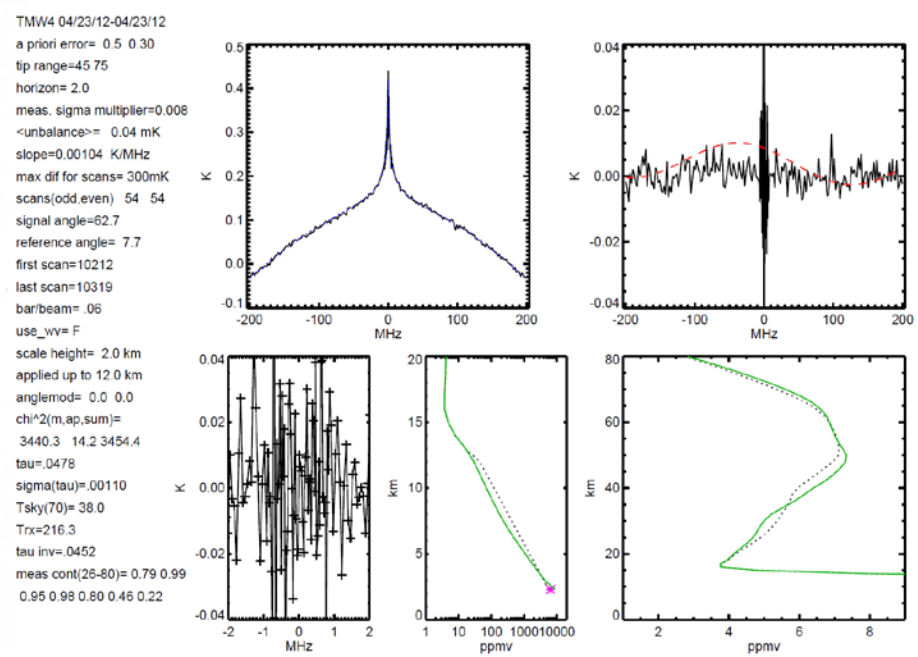
# Two different instruments, Two different antennas, Two different locations, Similar waves

Two different antennas of the same design can produce similar results if manufactured correctly

## WVMS 5

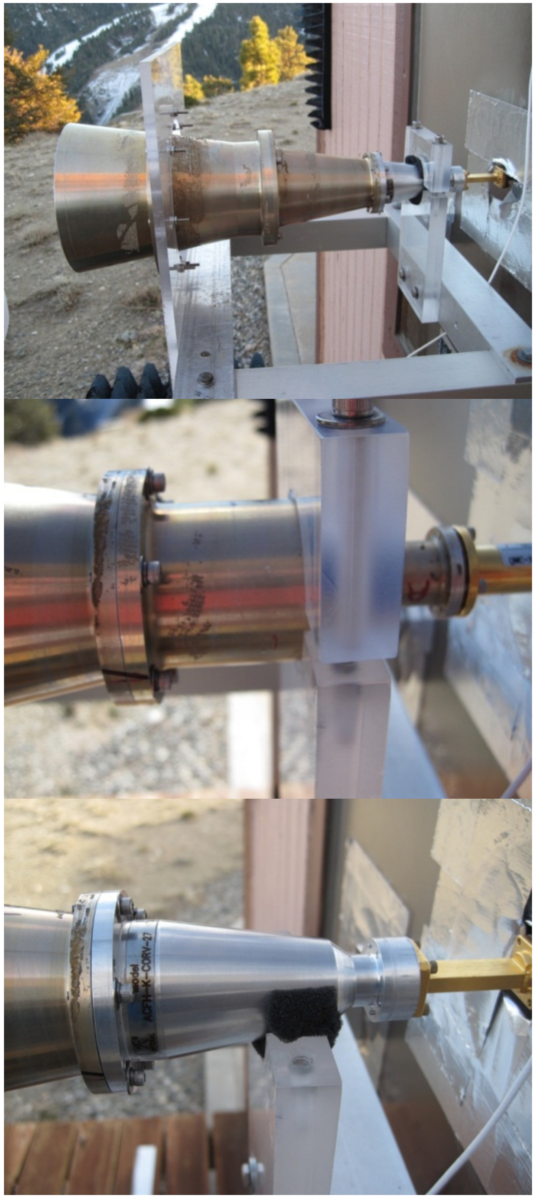



## WVMS 4

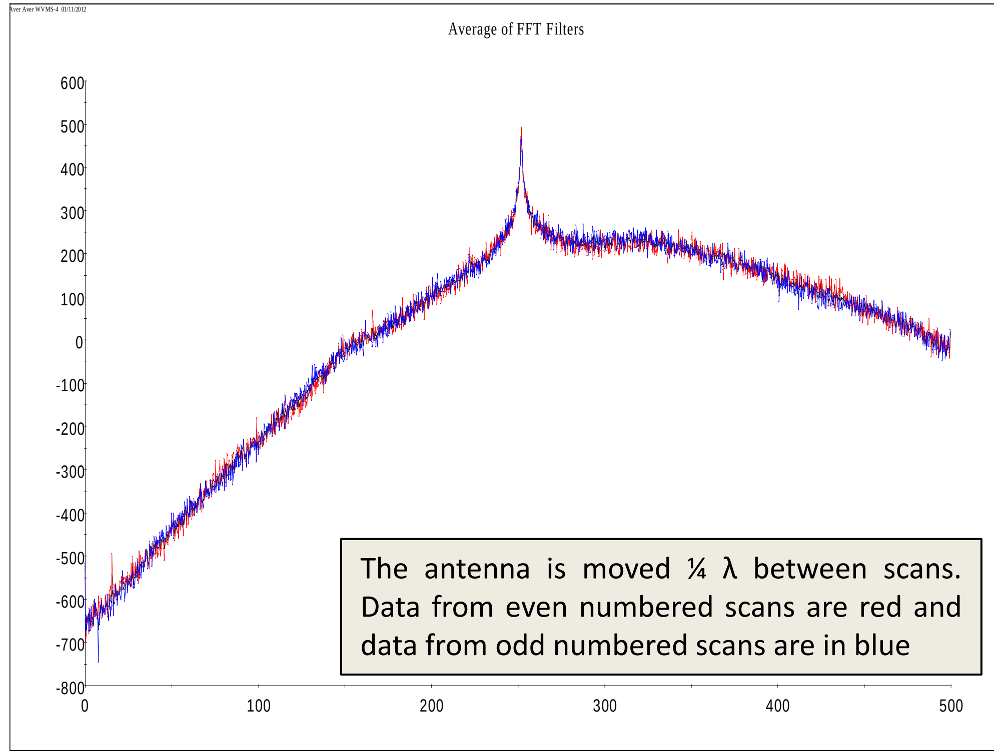



These are two good locations with instruments and antennas that are designed to be identical.

# What happens when an antenna is not manufactured correctly?



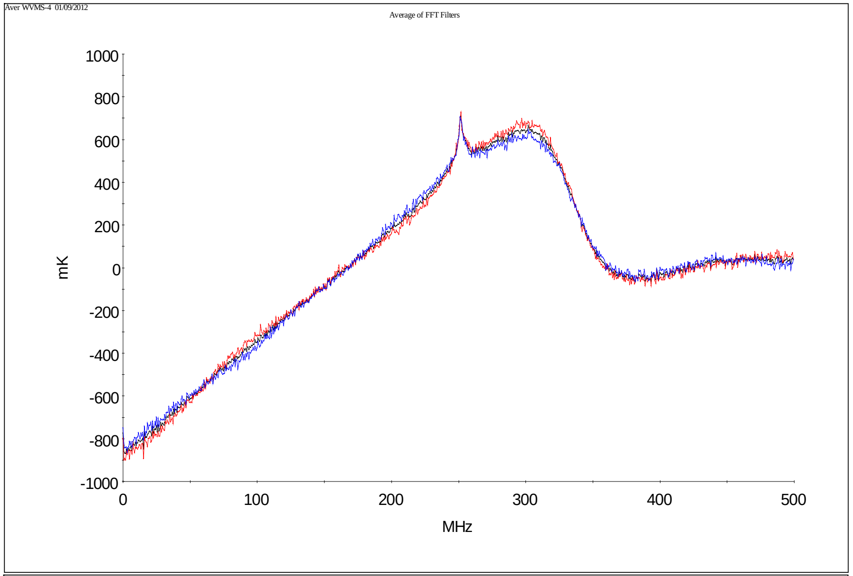
## The problem with NRL antenna 4



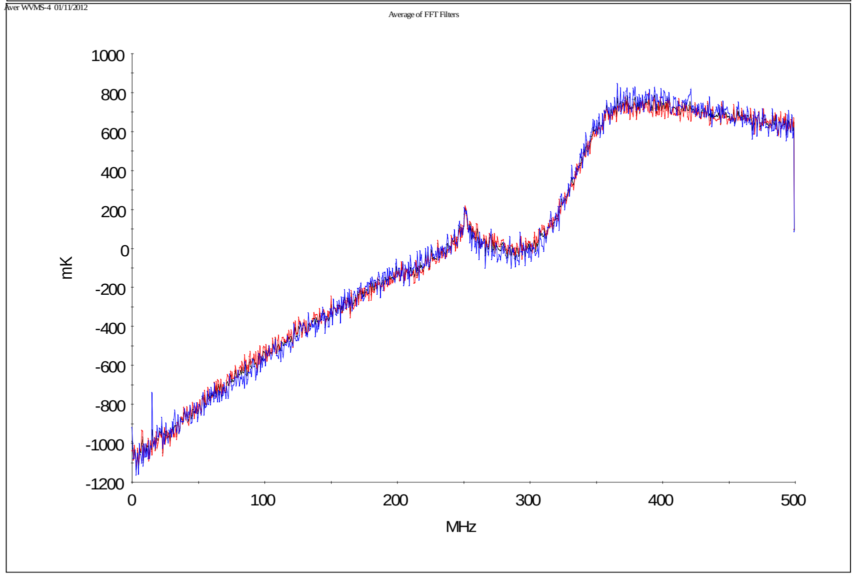

The antenna we sent to UPNA for repair we will call antenna 4. The reason we sent this antenna to UPNA was because it has this hump feature in the spectrum. You will notice the humps on the left and right side of the spectrum along with a slightly steeper slope.

# Antenna 4 with new segment

This plot shows the result of Antenna 4 with the new segment from UPNA installed and the reference bar at one meter. As you can see there is a sharp feature on the right hand side of the spectra.

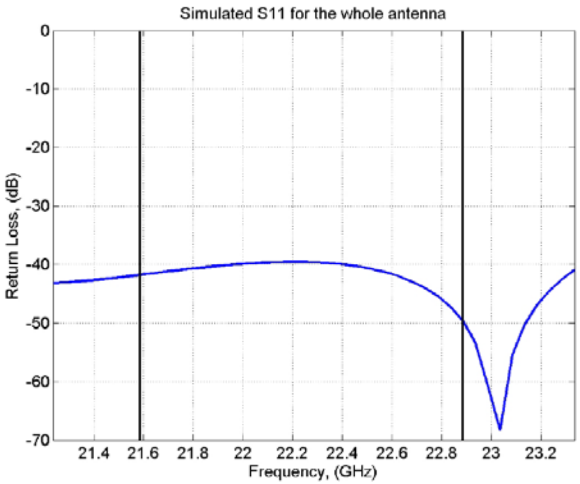



This plot shows the result of Antenna 4 with the new segment from UPNA installed and the reference bar at two meters. As you can see this same feature changes signs. Clearly this is a reflection /return loss issue.

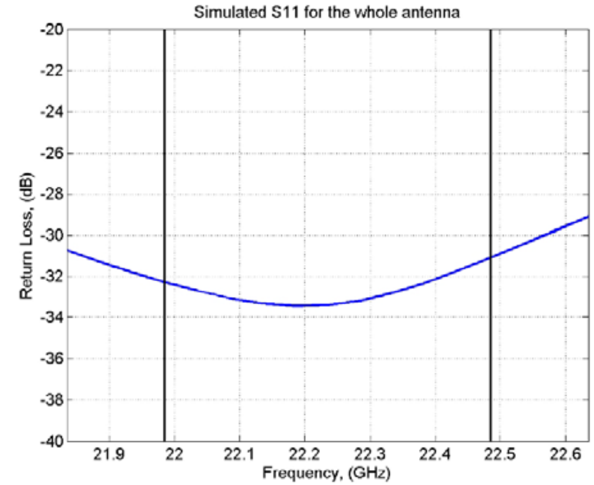


# Reflectivity/ Return Loss may be the key to making good antennas for this purpose

## UPNA FzK

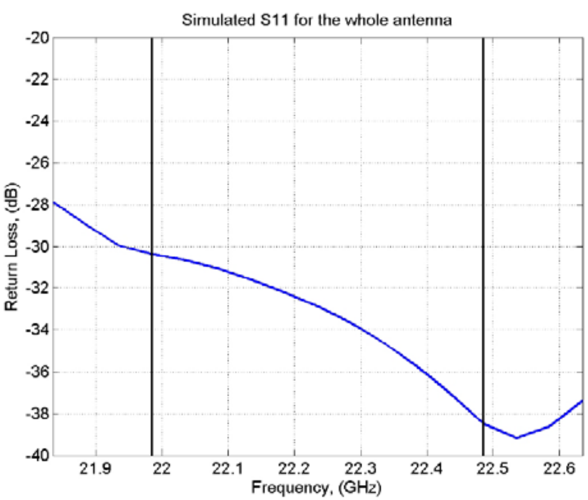


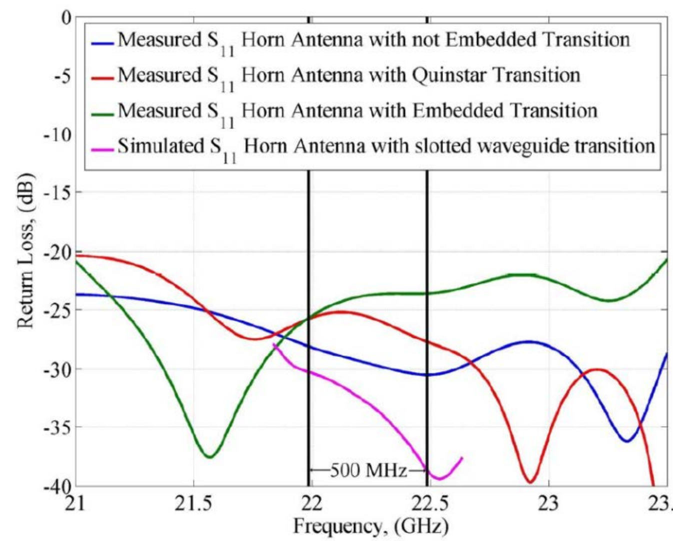

## NRL




It is theorized that designing an antenna where the return loss is flat across the entire frequency of interest would help mitigate reflections caused by placing the bar in only part of the beam in the near field of the antenna.

## UPNA NRL



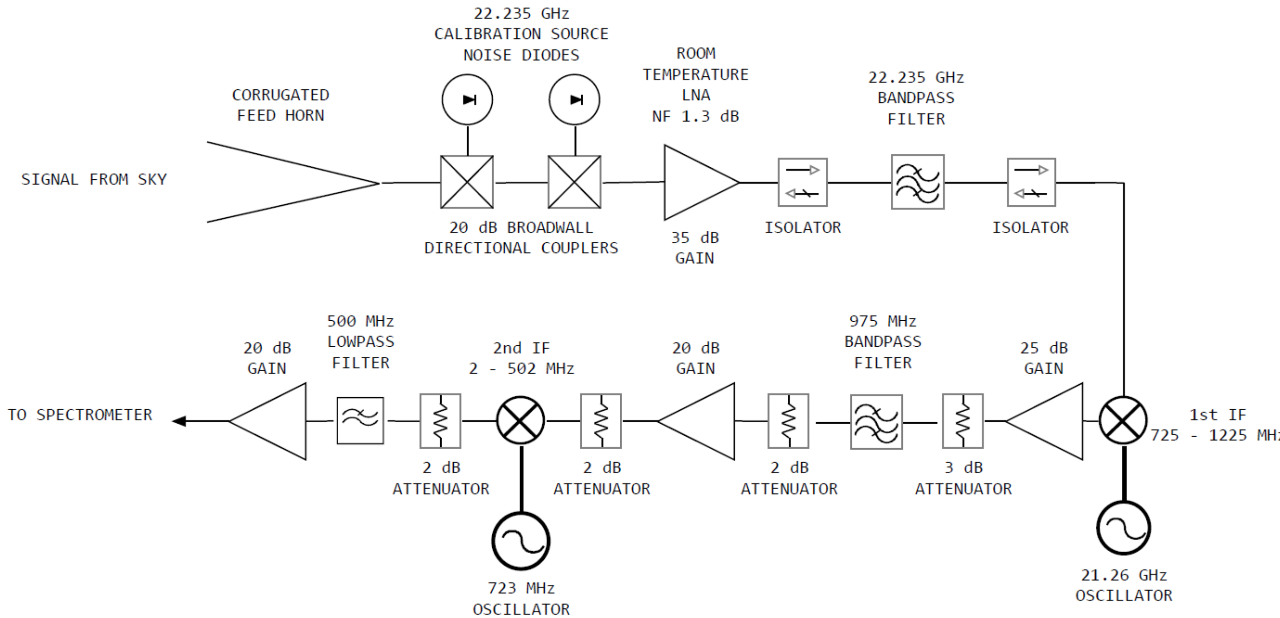
## Summary

- Return loss is directly related to the baseline created by the antenna
- In the near field antennas can be sensitive in frequency in both planes
- The baseline changes with reference angle (where the bar is in the beam)
- The placement of the bar is critical both in height and angle
- The further away the bar is from the horn the better
- The angled bar works better for our old horns but not for the new one
- ¼ $\lambda$ movement of antenna is critical

Most of what is shown here are extreme cases. As you start hunting small waves in your retrieval residuals you will see how very small changes really do matter to the profile. The key to long term measurements is stability in these baselines.

End

# Block Diagram for WVMS 4



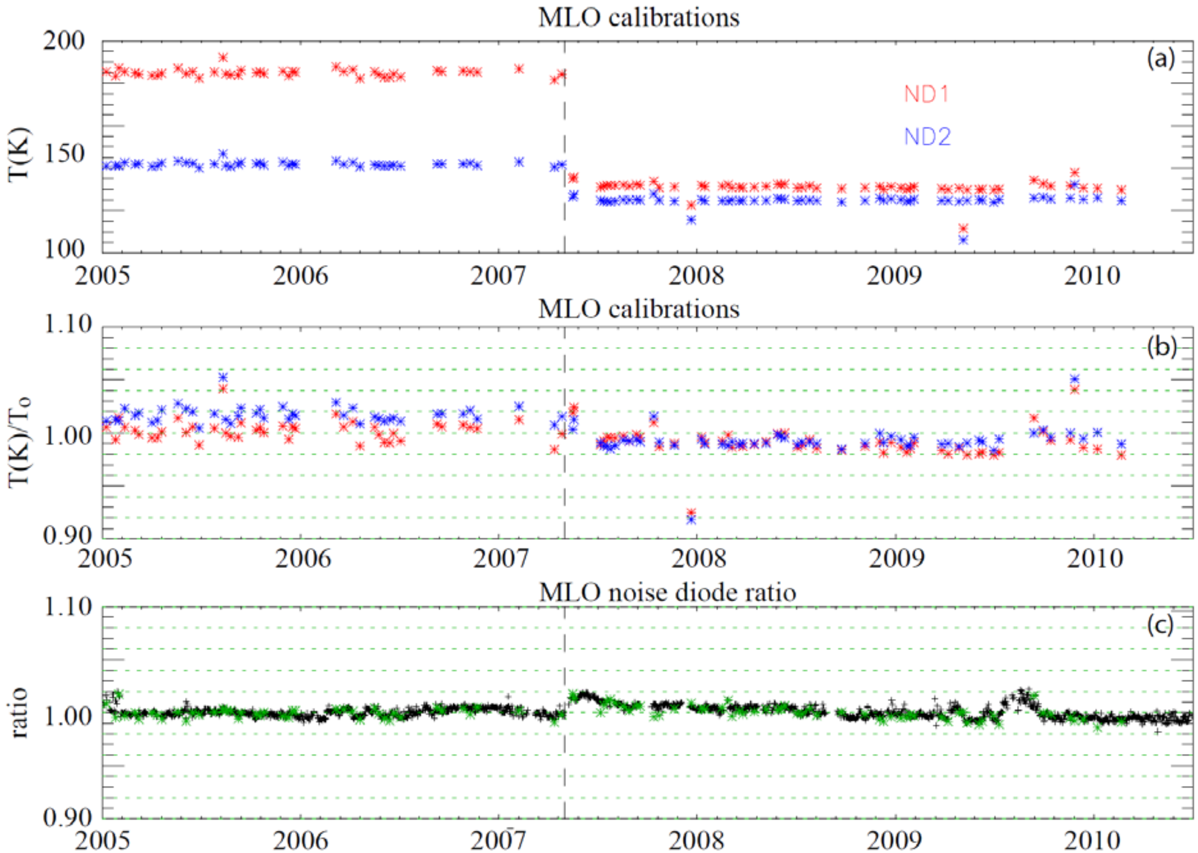
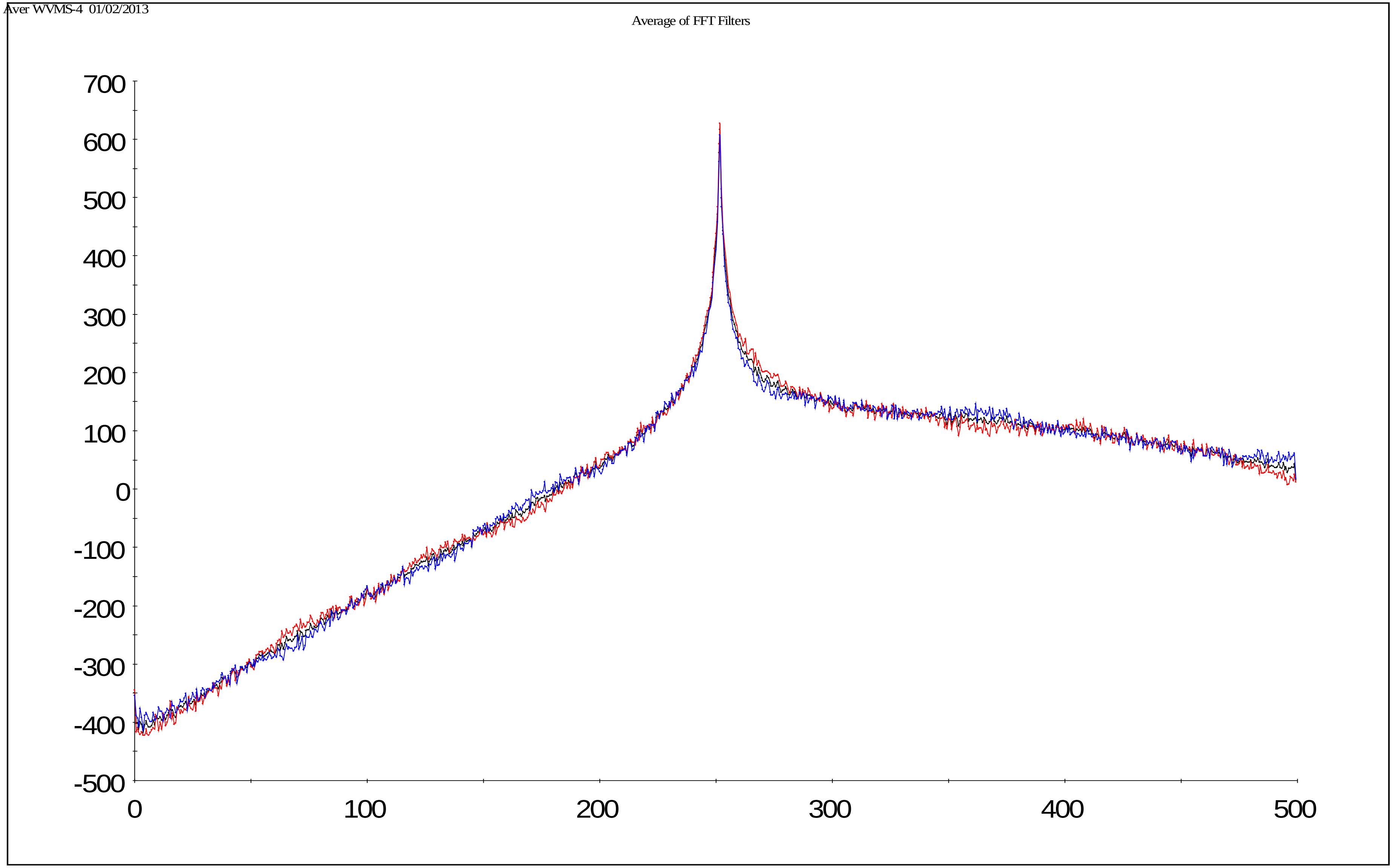
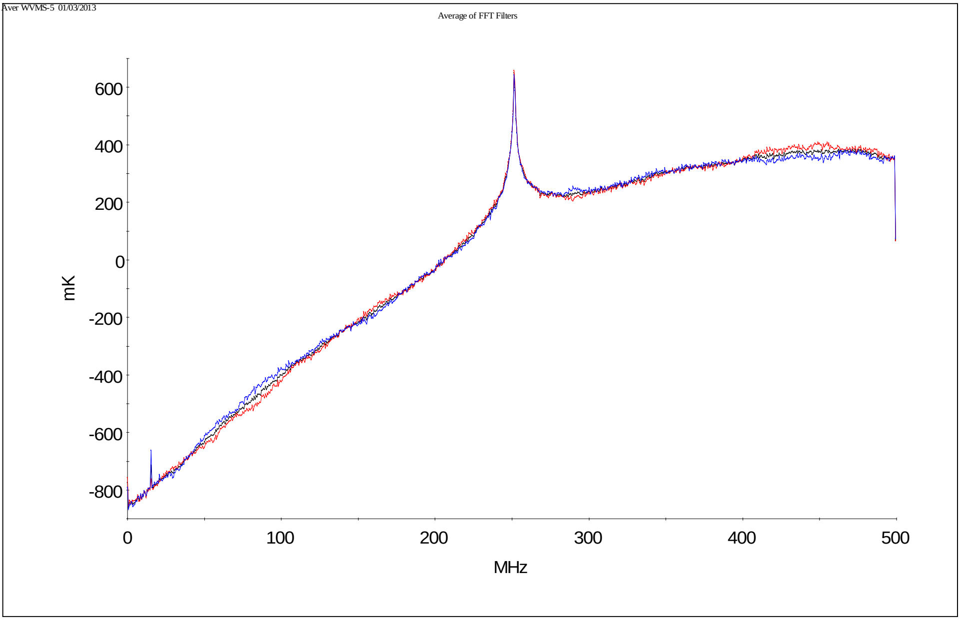
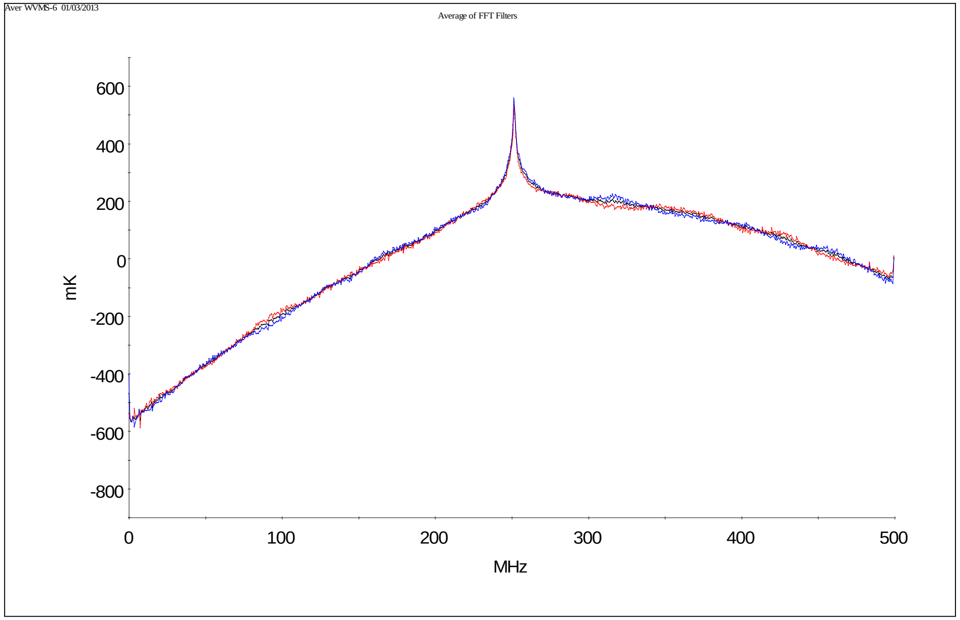
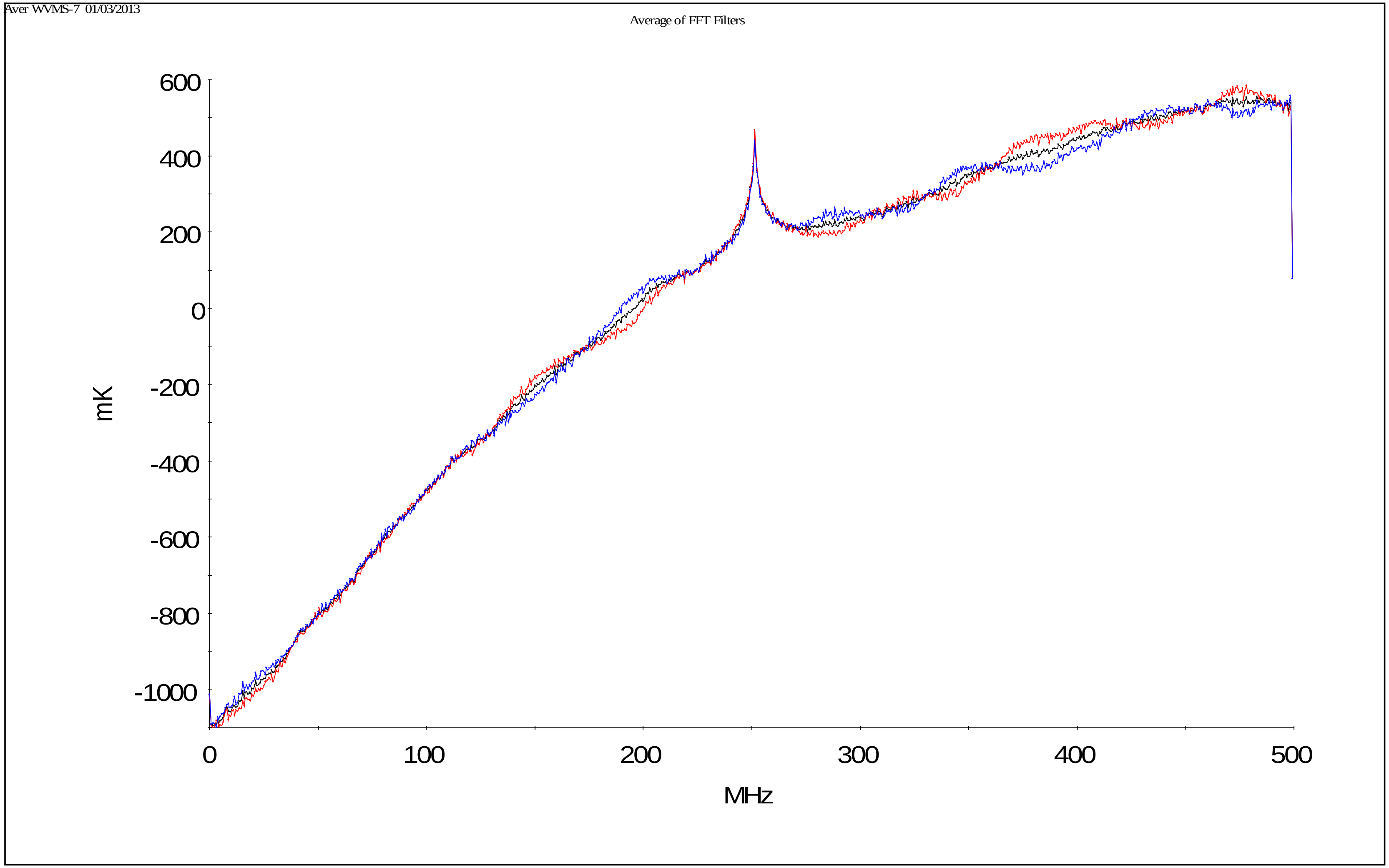



Figure 7 – Top panel (a): Calibrated temperature of primary noise diode (ND1; red) and secondary noise diode (ND2; blue) on WVMS3, as obtained by an external hot-cold calibration. The jump in 2007 is from the replacement of the waveguide couplers. Middle panel (b): Temperatures from top panel, red and blue, normalized to the median value of primary and secondary noise diode outputs, respectively, for the periods January 2005-March 2007, and March 2007-March 2010. Bottom panel (c): Ratio of ND1/ND2 (normalized as in middle panel) from the external calibration (green). Also shown is daily median of the ratio of ND1/ND2 (normalized as in middle panel), as determined from the internal noise diode comparison.


Aver WVMS-4 01/02/2013
Average of FFT Filters
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
0
100
200
300
400
500


Aver WVMS-5 01/03/2013
Average of FFT Filters
600
400
200
0
-200
-400
-600
-800
mK
0
100
200
300
400
500
MHz


Aver WVMS-6 01/03/2013
Average of FFT Filters
600
400
200
0
-200
-400
-600
-800
mK
0
100
200
300
400
500
MHz


Aver WVMS-7 01/03/2013
Average of FFT Filters
600
400
200
0
-200
-400
-600
-800
-1000
mK
0
100
200
300
400
500
MHz