Modelling Radar Biases Due to Antenna Topology and Operating Frequency

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Z_{DR}

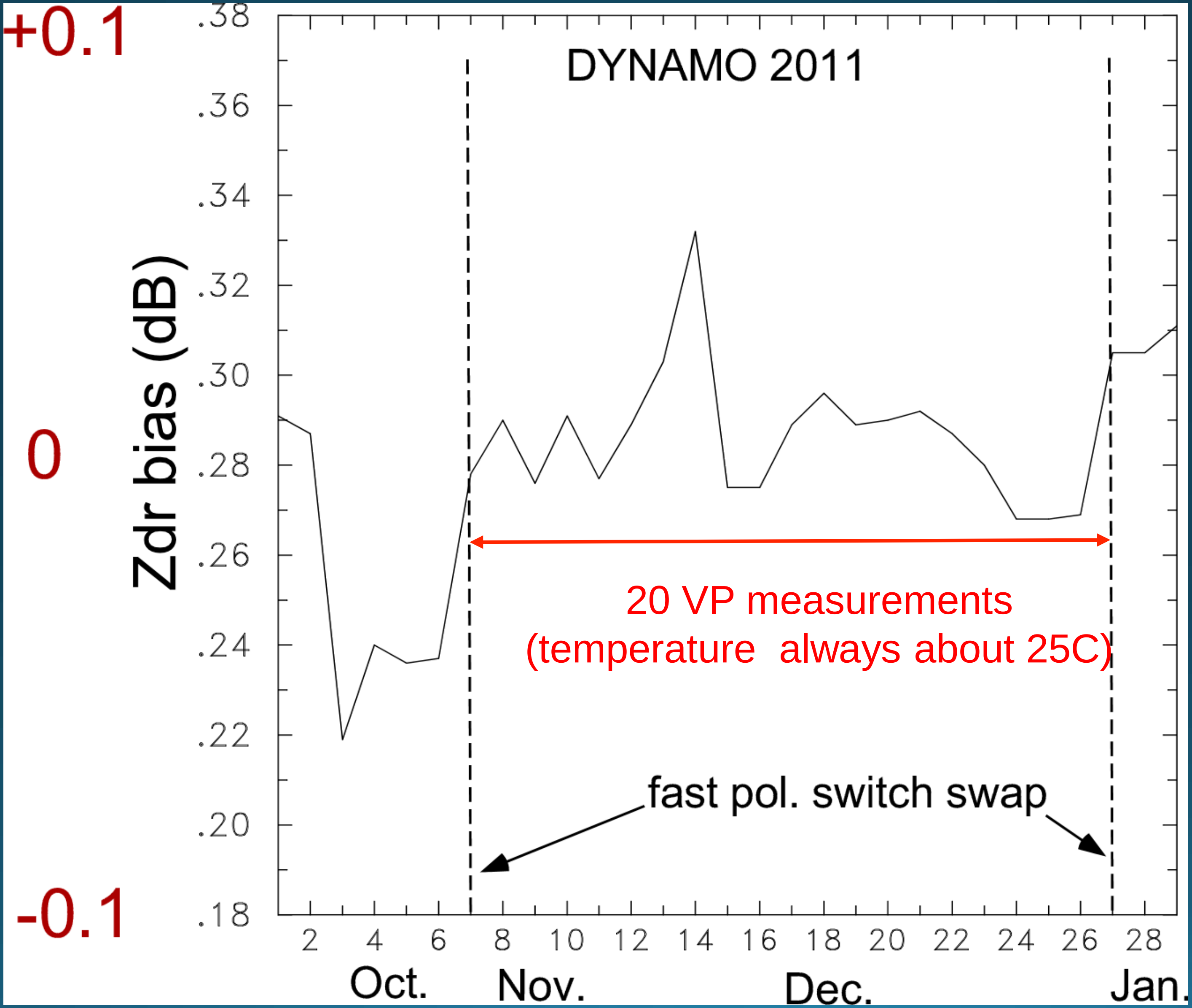
1976 was A long, long time ago…..

- First Star Wars Movie!!
- Human Accomplishments since 1976:
  - Personal computer revolution
  - Human genome mapped
  - Cosmic string theory introduced (1976, Thomas Kibble)
  - Internet
  - GPS navigation
  - Cell phones
- But what can't we do well yet???
- Why is that Yoda??

S-Pol Zdr Calibration Story

Previous Zdr VP Cal Experience with S-Pol

Zdr bias very stable!!

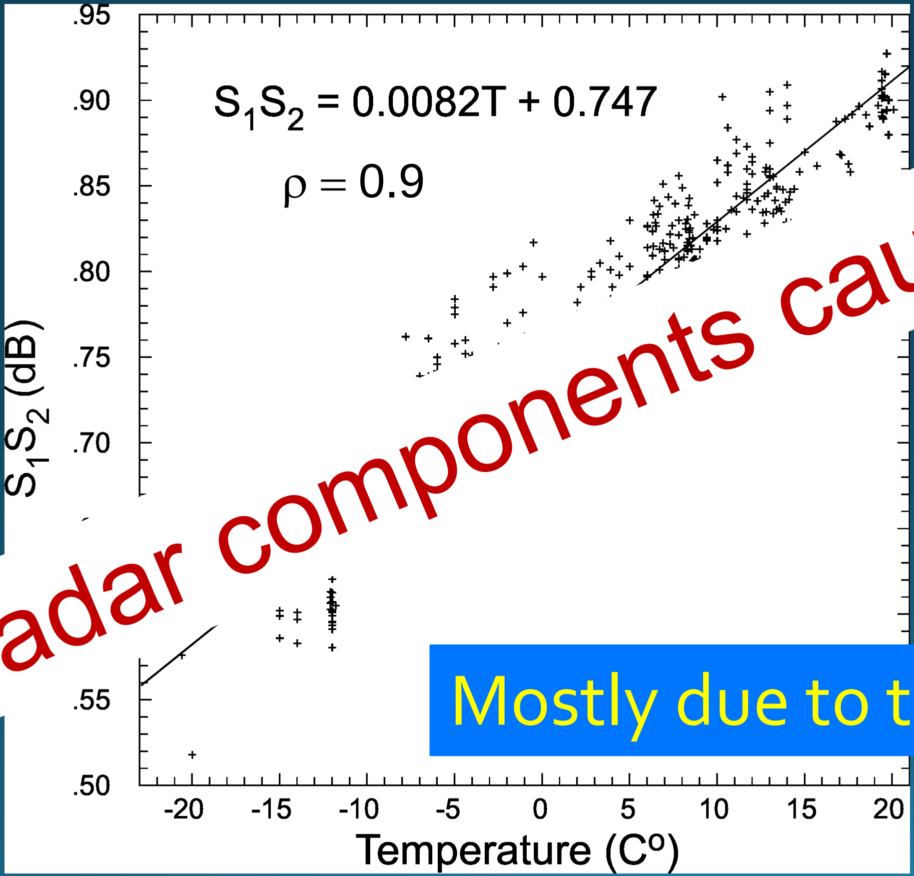


Zdr bias versus Air Temperature

MASCRAD Experiment: 104-2015 in Front Range

Data gathered in Colorado Front Range with S-Pol

December 24, 26, 2014 , January 9, 10, 11,12, 15, and Feb. 6, 22, 27, 2015



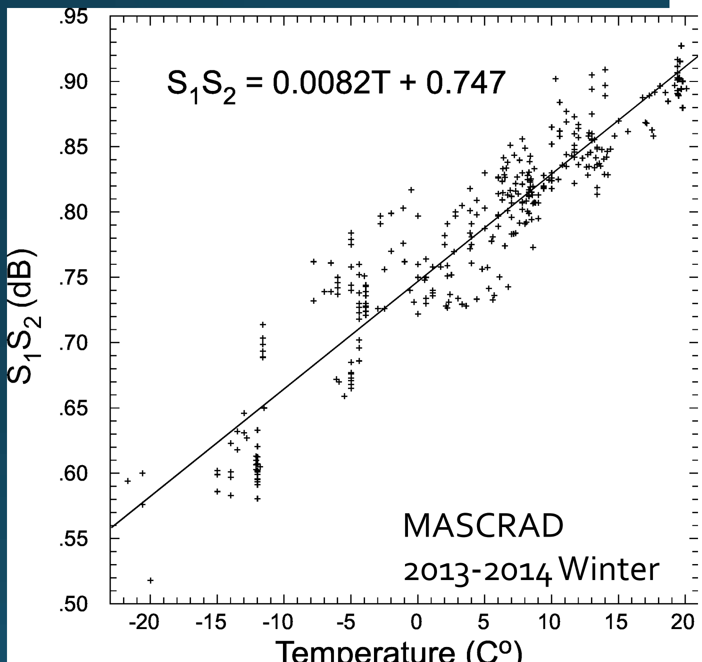
What radar components cause this!!

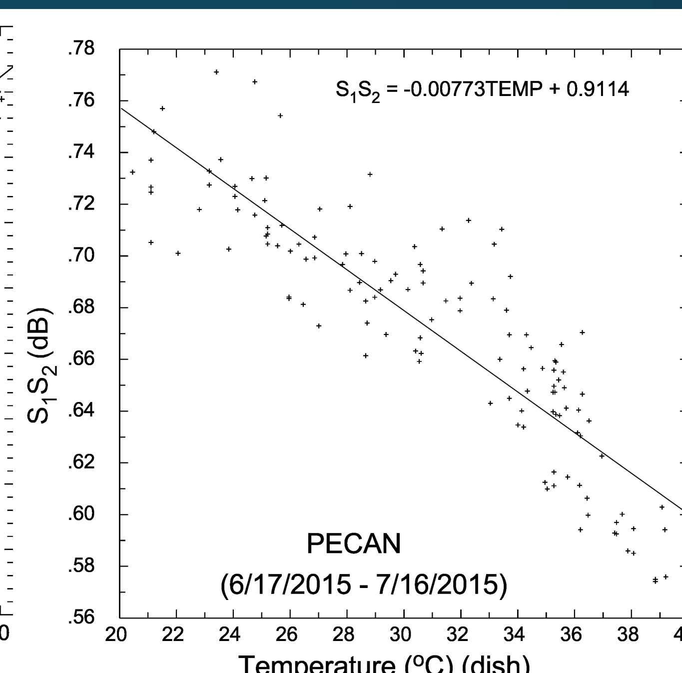
Mostly due to the antenna

MASCRAD and PECAN Experiments
S1S2 versus Temperature

RF diff. gain < 0.03dB

Temperature Ranges do not Overlap





Tear down/set up.

Microwave absorber on struts

BACKGROUND

Z_{dr} Calibration:

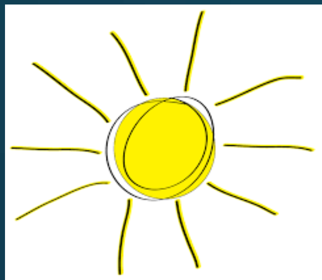
Crosspolar Power Technique

$$Z_{dr}^{cal} = Z_{dr}^{m} S_1 S_2 \frac{P_{xV}}{P_{xH}}$$

Solar power ratio

Crosspolar power ratio

Using the previous regression fit of S1S2 to temperature, PECAN Zdr was calibrated.

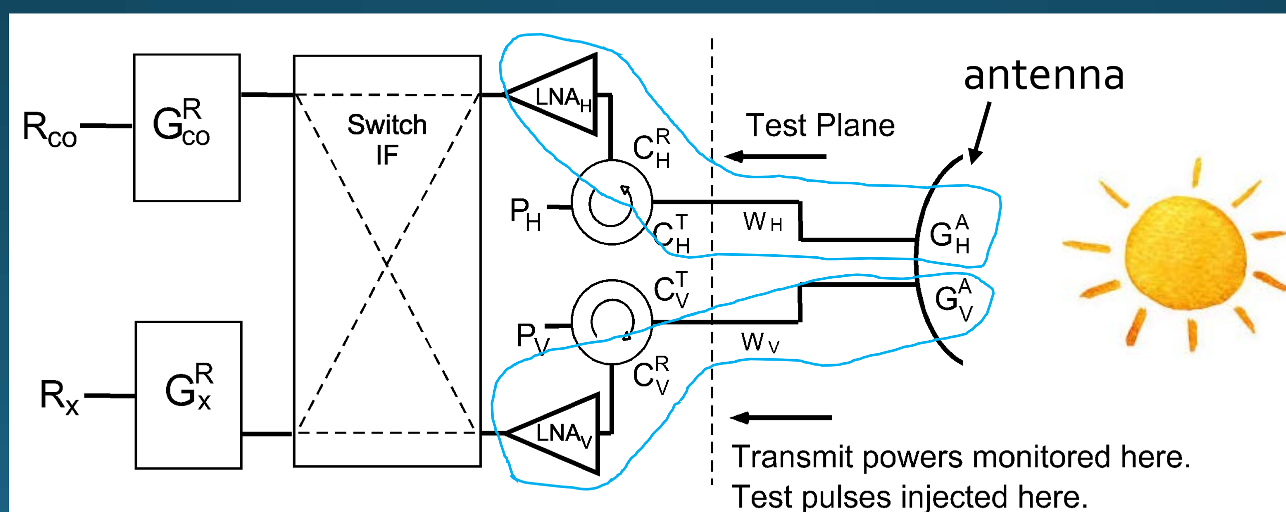


S1S2 Consists of Two Terms

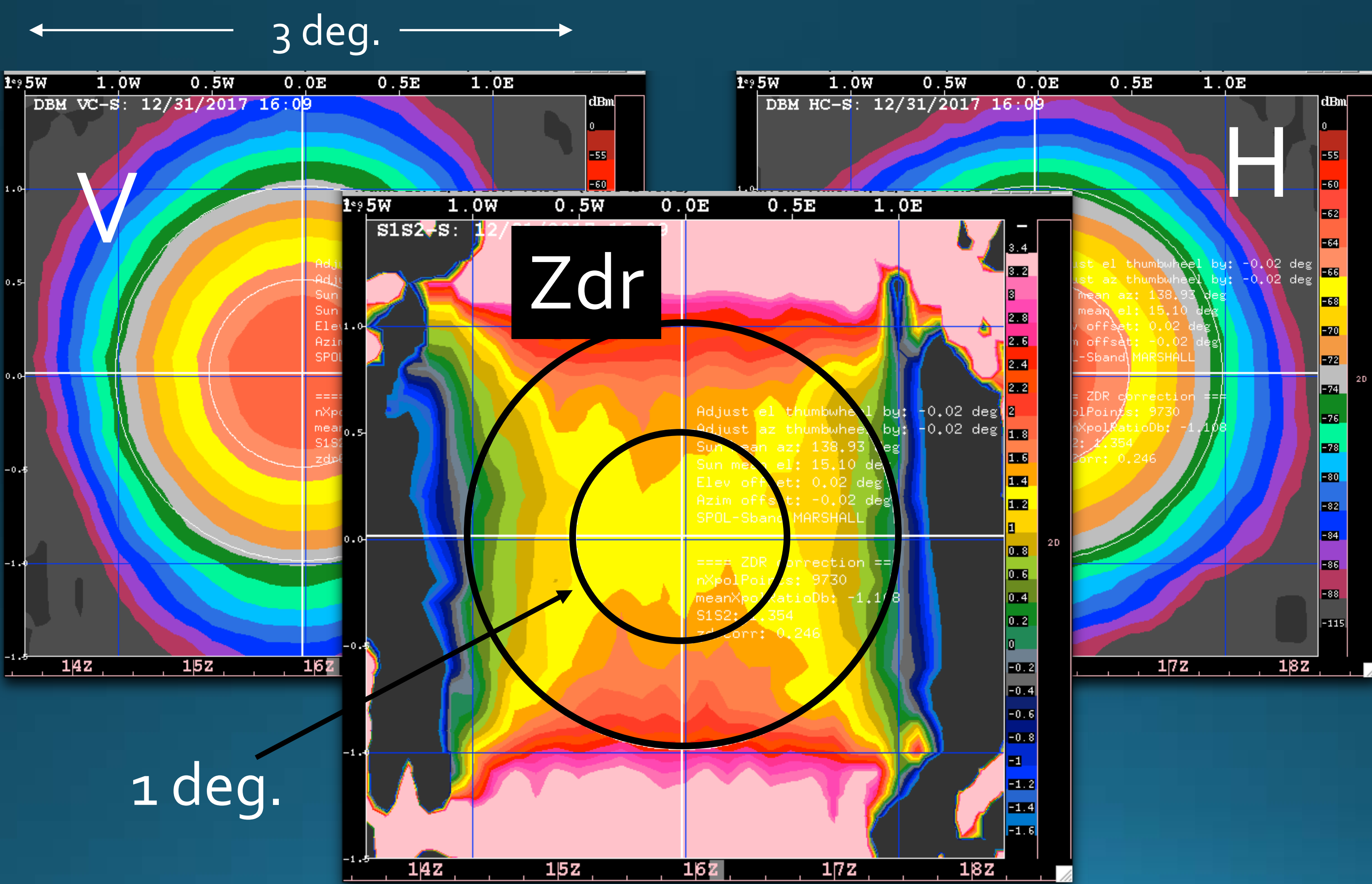
Antenna

RF Receiver

$$S_1S_2 = \frac{(W_V G_V^A C_V^R LNA_V)^2}{(W_H G_H^A C_H^R LNA_H)^2}$$

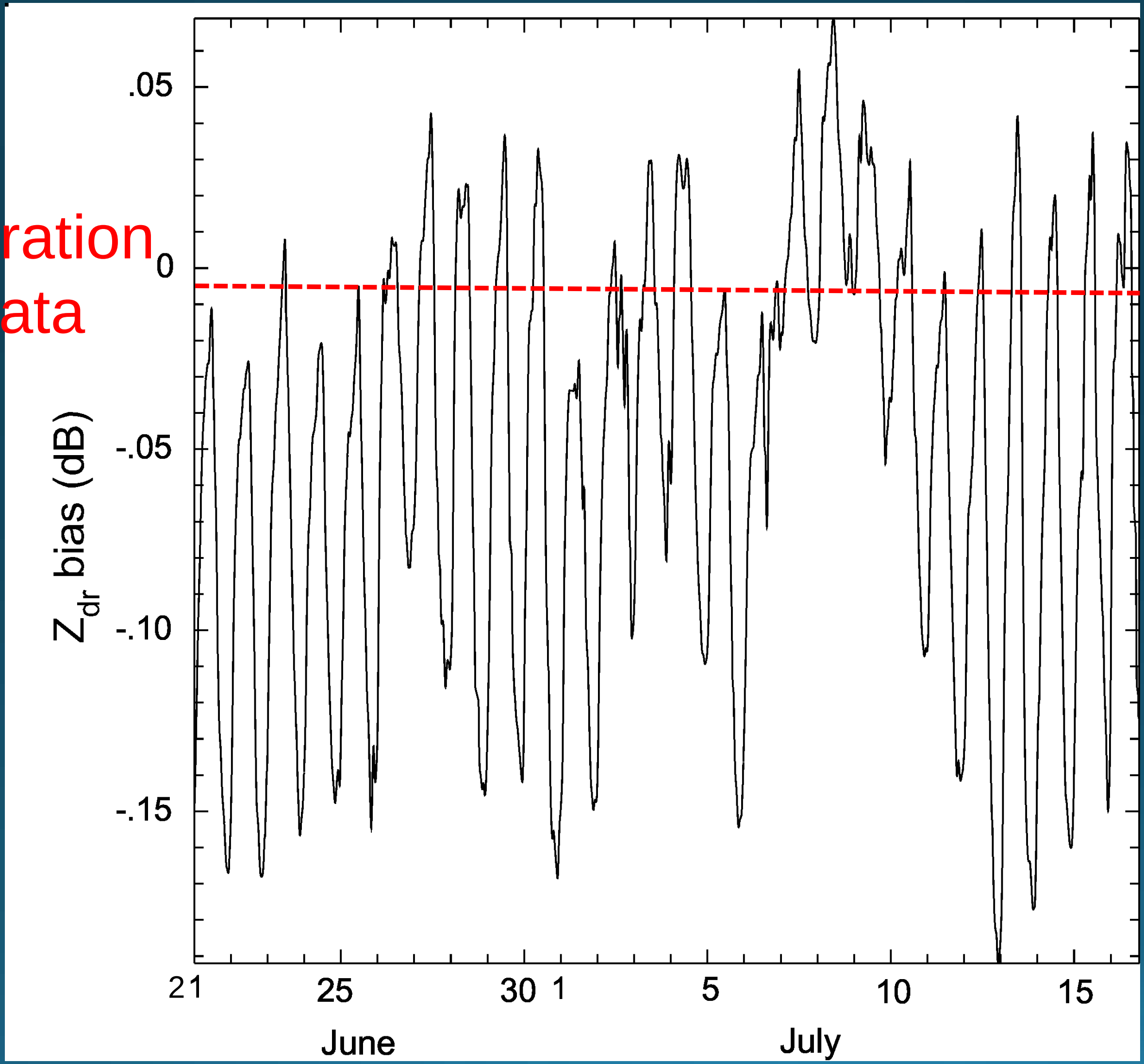


Experimental Solar Antenna Patterns



Zdr Bias Calibration for PECAN

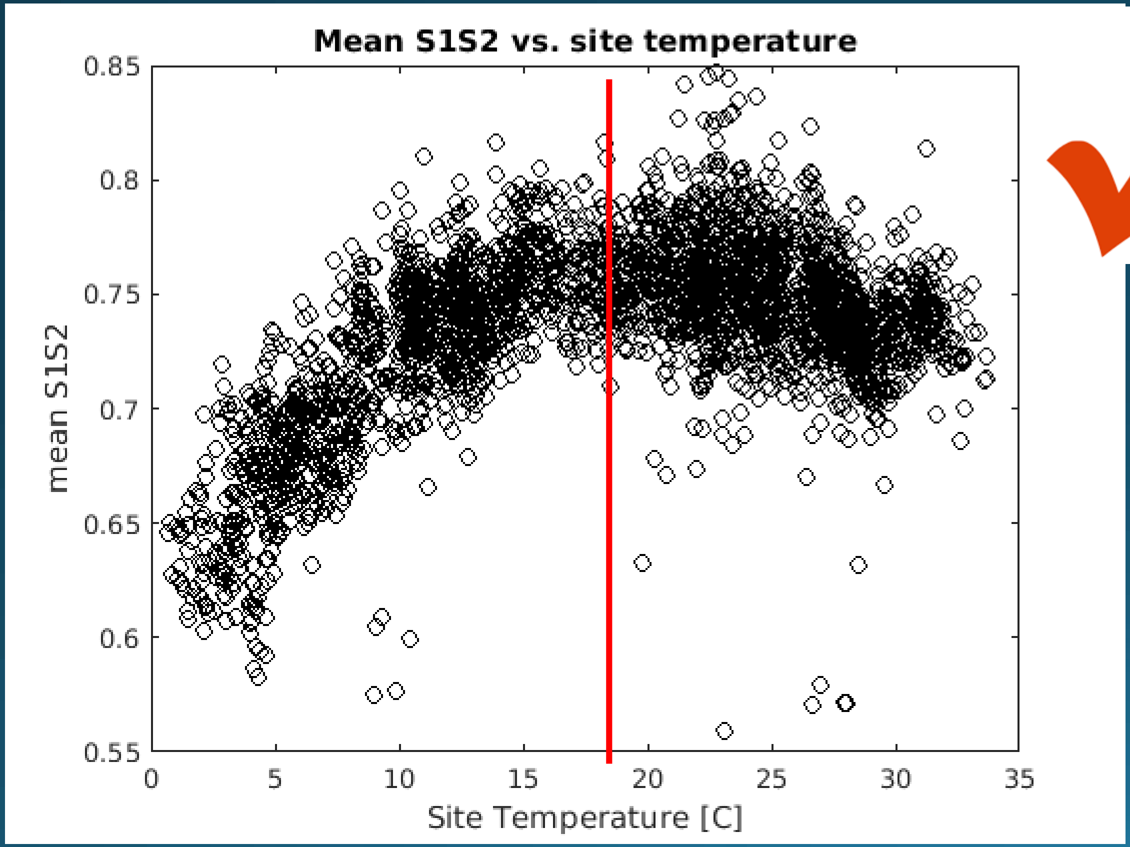
Legacy calibration
from VP data



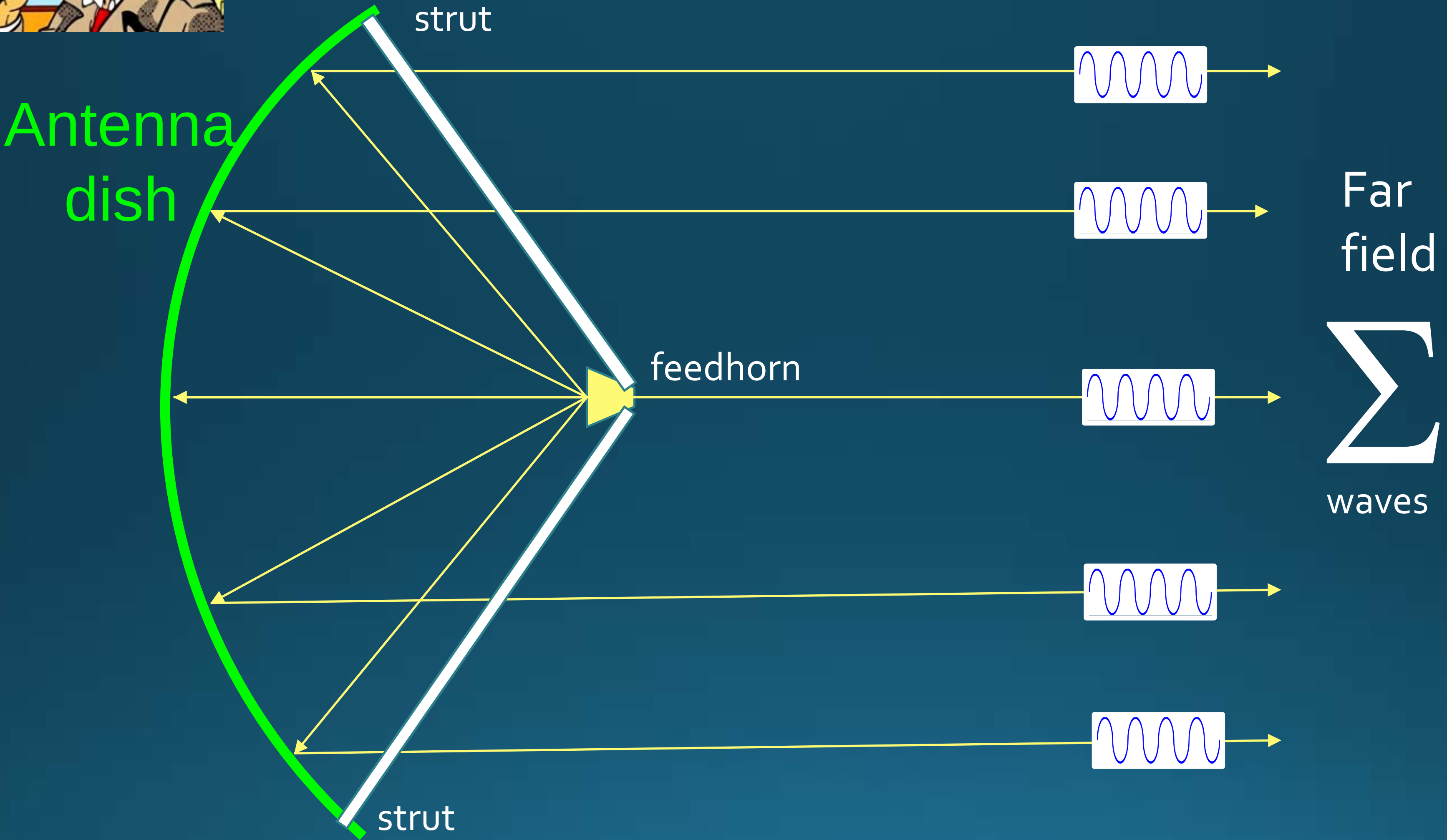
S_1S_2 Measurement from this Spring

S-Pol at Marshall Fieldsite, April – June, 2017

Indeed there is an inflection point at 18 to 20C!!



Likely Mechanism for Zdr Bias Variations

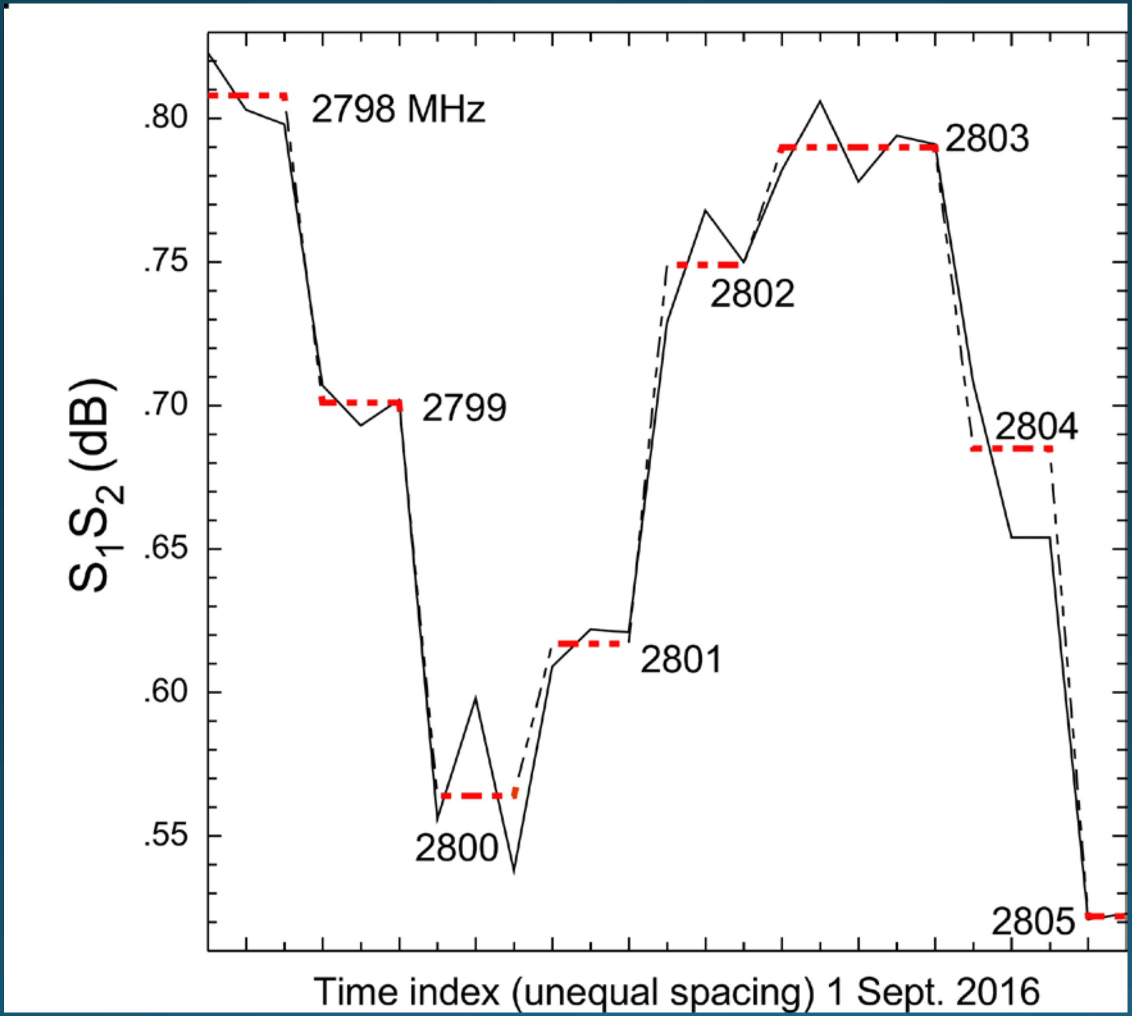


As metal expands , Phase relationships change

Idea

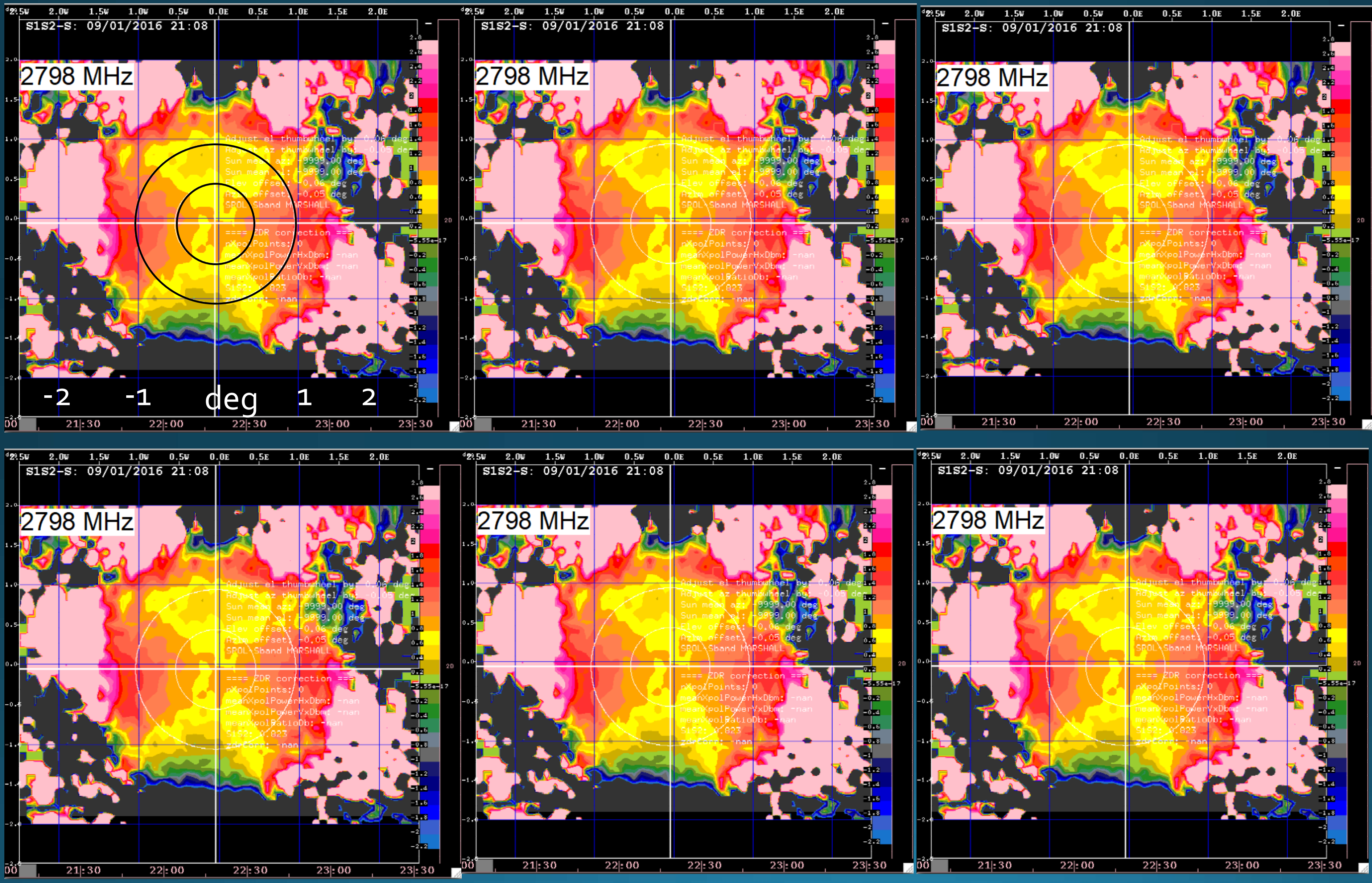
- Change phase relationships by changing frequency

S_1S_2 as a Function of Frequency

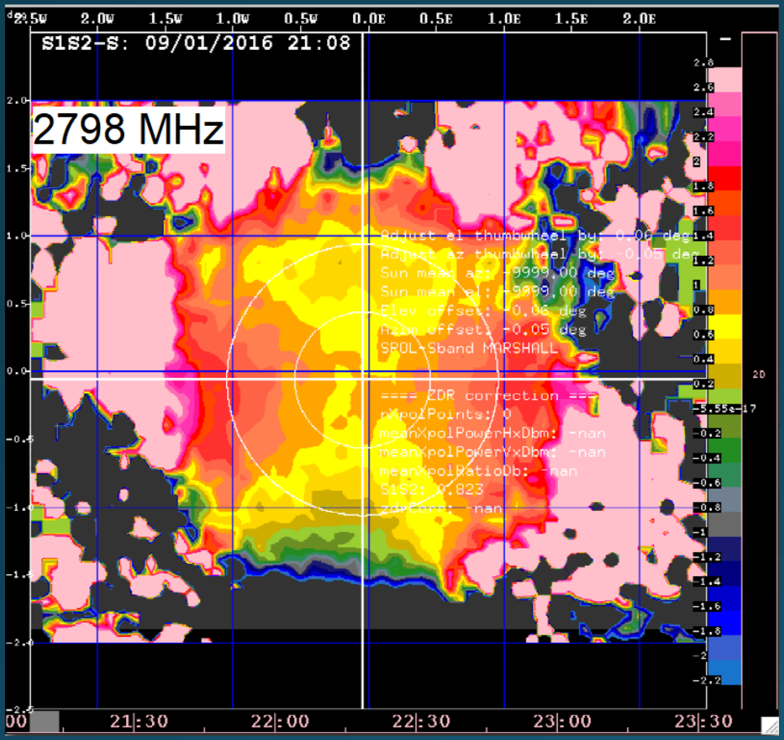


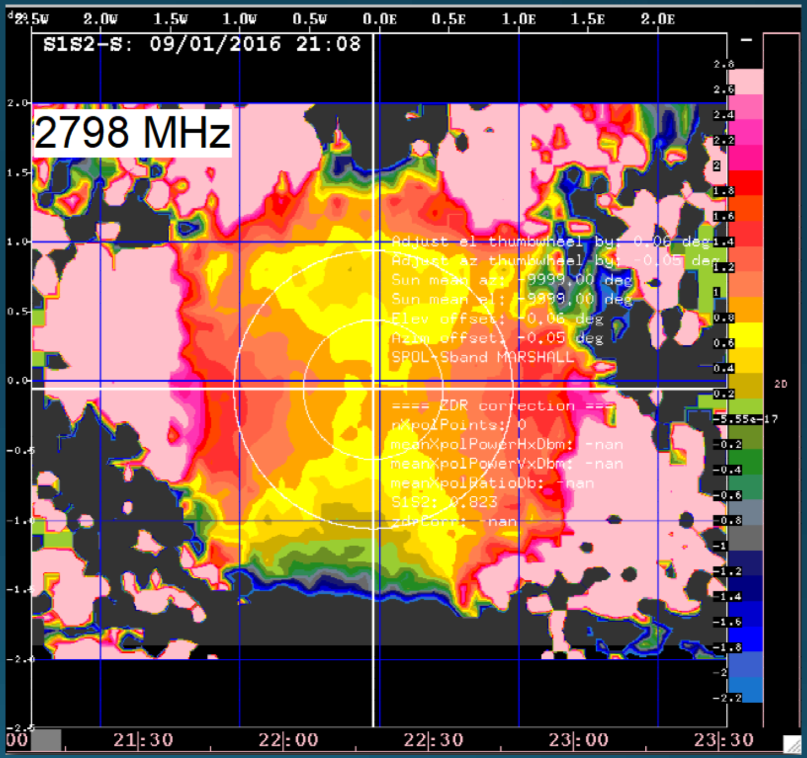
A change of 2 MHz causes a diff. gain change of 0.25dB!

Solar V/H power or Zdr Antenna Patterns



…continued Zdr Antenna Patterns



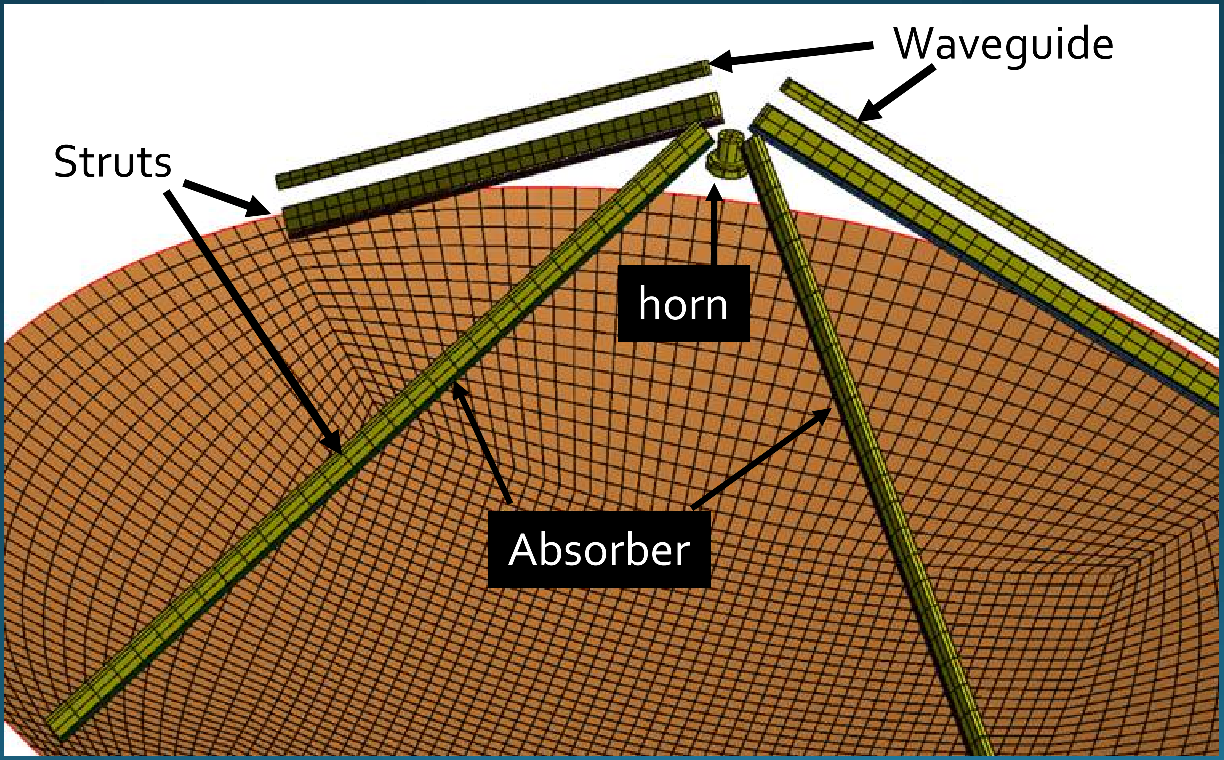


Dish Shape: Photogrametry

- About 1400 optical patches on dish, struts and feedhorn.
- About 50 pictures around the edge of dish
- Fit a parabola
- RMS error across the dish: ~0.03 inch
- Exact dimensions of the feedhorn (CAD drawing)

Numerical Modeling of Antenna

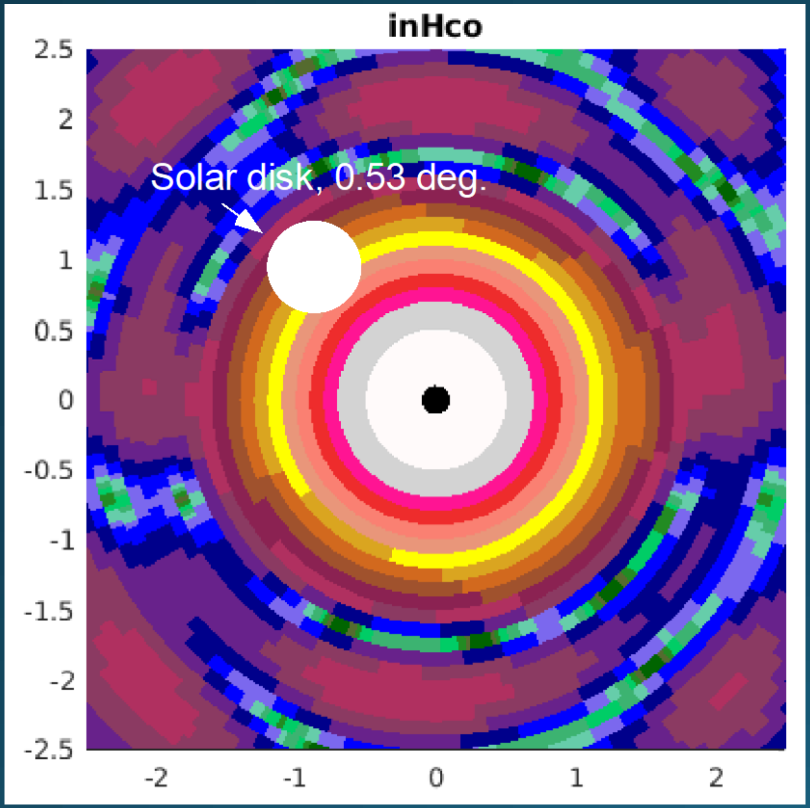
- Using GRASP (General Reflector Antenna Software Package) by TICRA of Denmark with the Method of Moments. This is an exact full wave method, which takes into account all mutual coupling, blockage and near-field effects.
- Exact dish shape
- Simulated feed horn patterns (from the horn CAD drawing)
- COMPLEX COPOLAR AND CROSS-POLAR ANTENNA PATTERNS

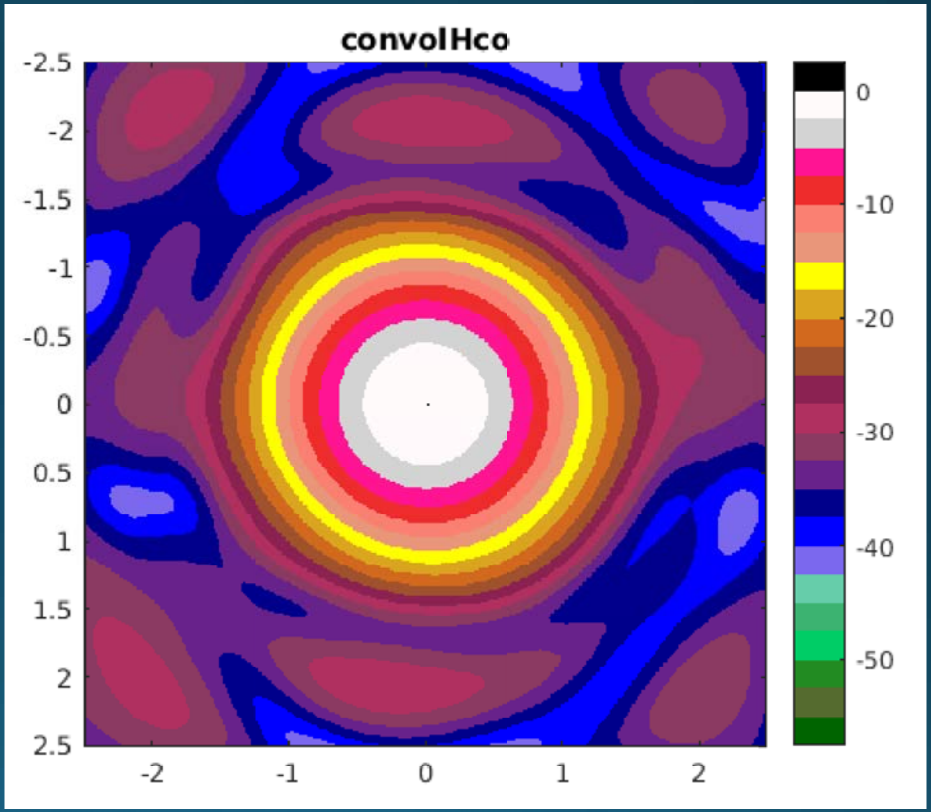


4 Cases Model

1. Full model
2. Without waveguide
3. Without absorber
4. Move feed horn phase center 3mm closer to dish

Convolve the Modeled Antenna Patterns with Solar Disk





Calculating Zdr from Model Data

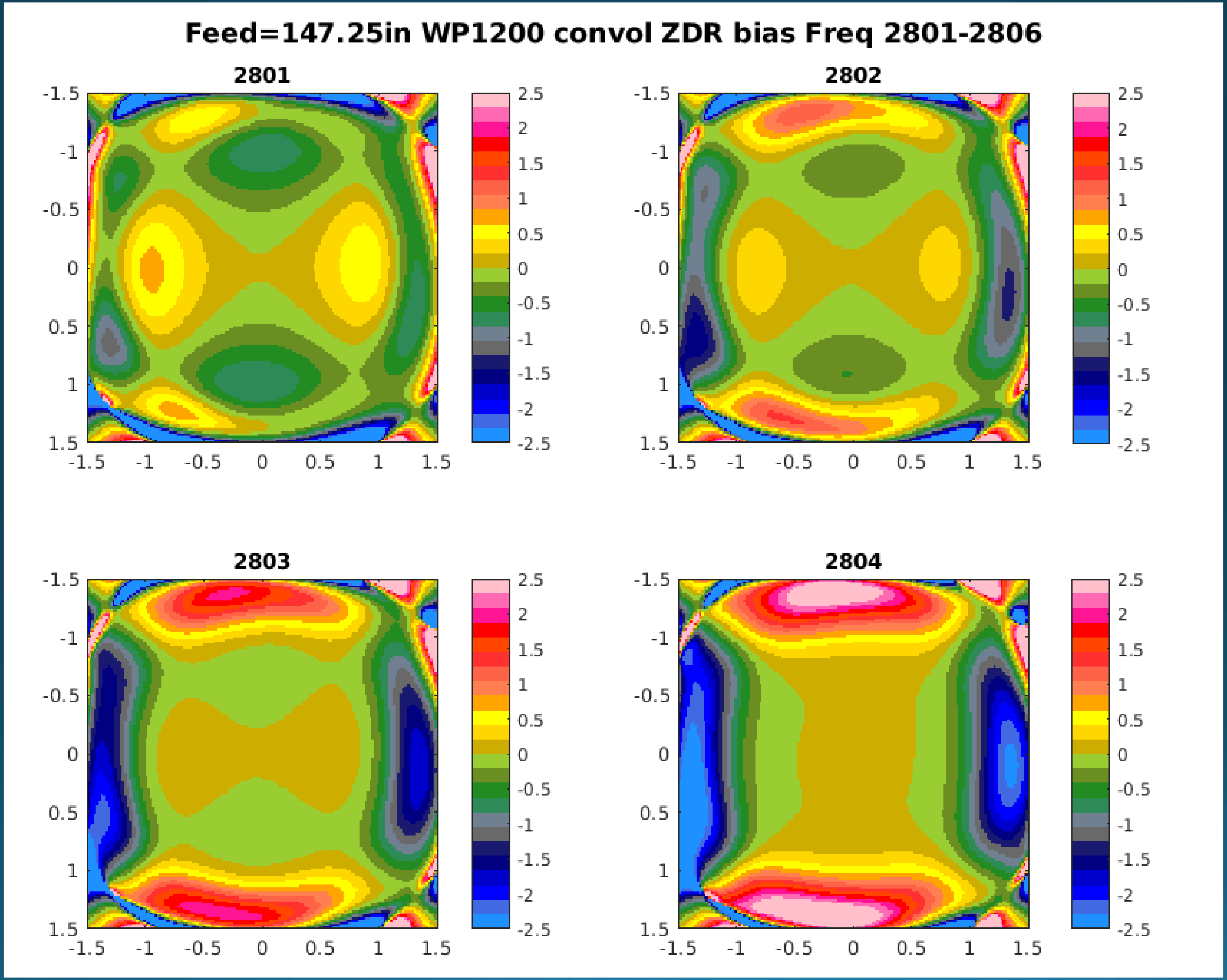
$$Z_{DR} = \frac{\int |f_{HH}^2 + f_{HV}^2|^2 \, d\Omega}{\int |f_{VH}^2 + f_{VV}^2|^2 \, d\Omega}$$

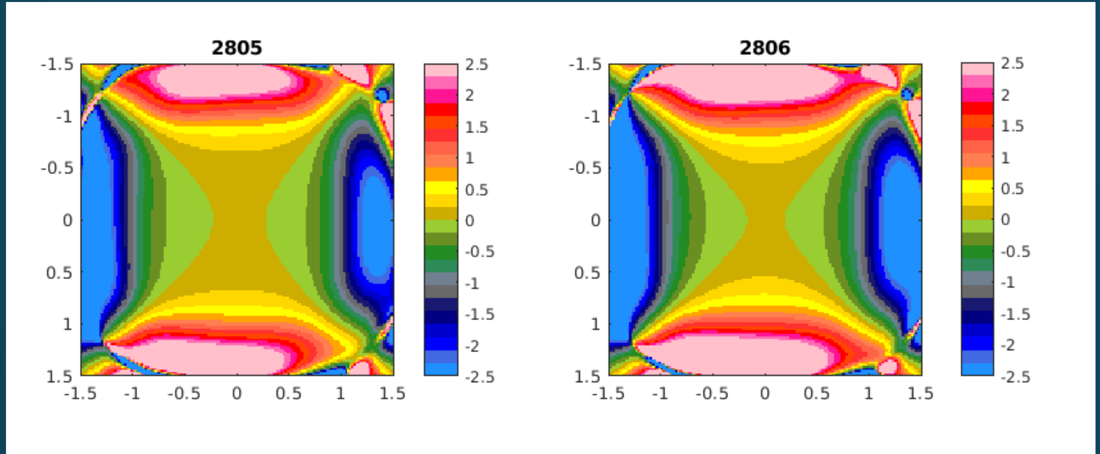
Complex antenna patterns!!

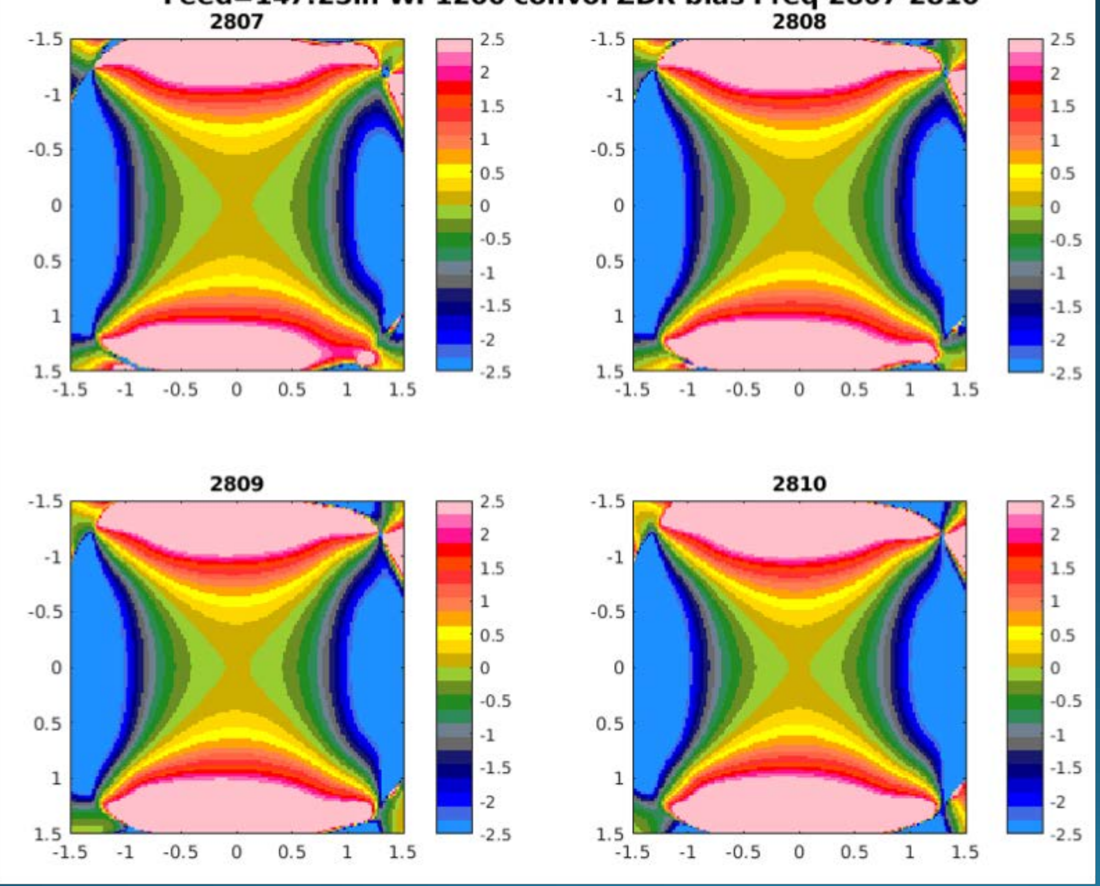
Chandrasekar and Keeler 1993

Modeled Zdr Antenna Patterns

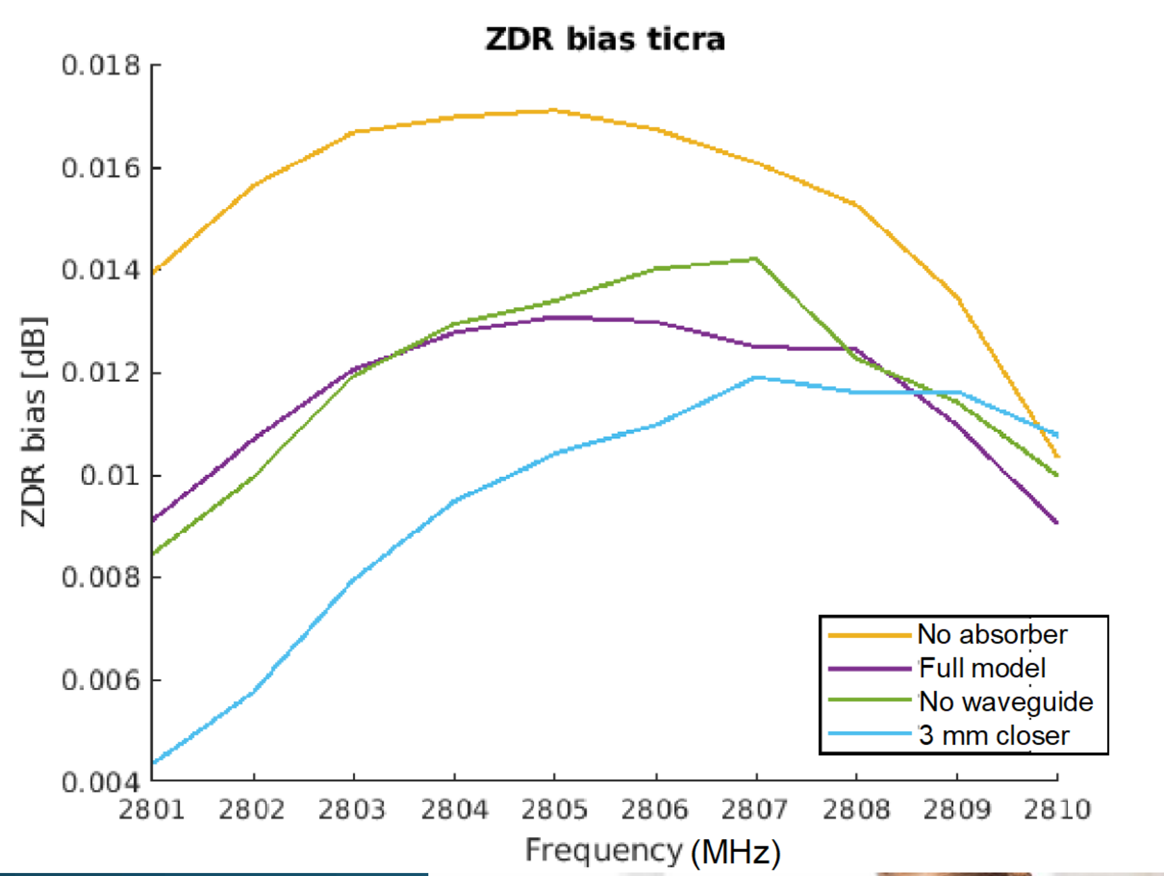
(convolved with solar disk)



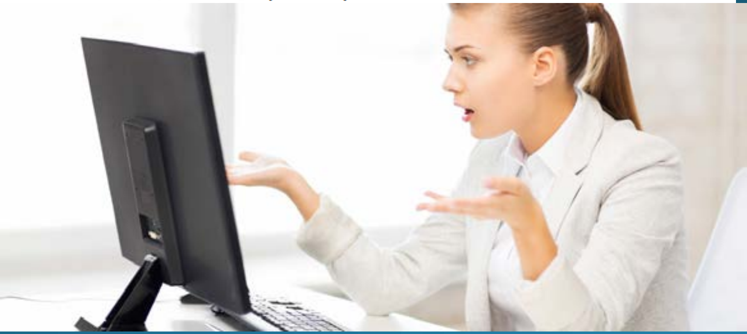

2805
2806


2807
2808
2809
2810

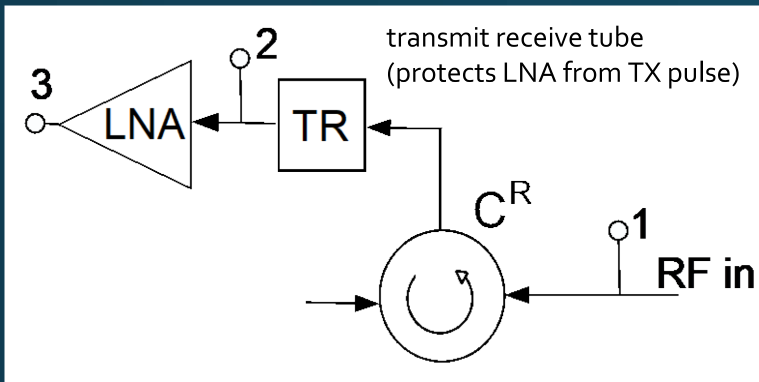
Integrated Zdr Bias



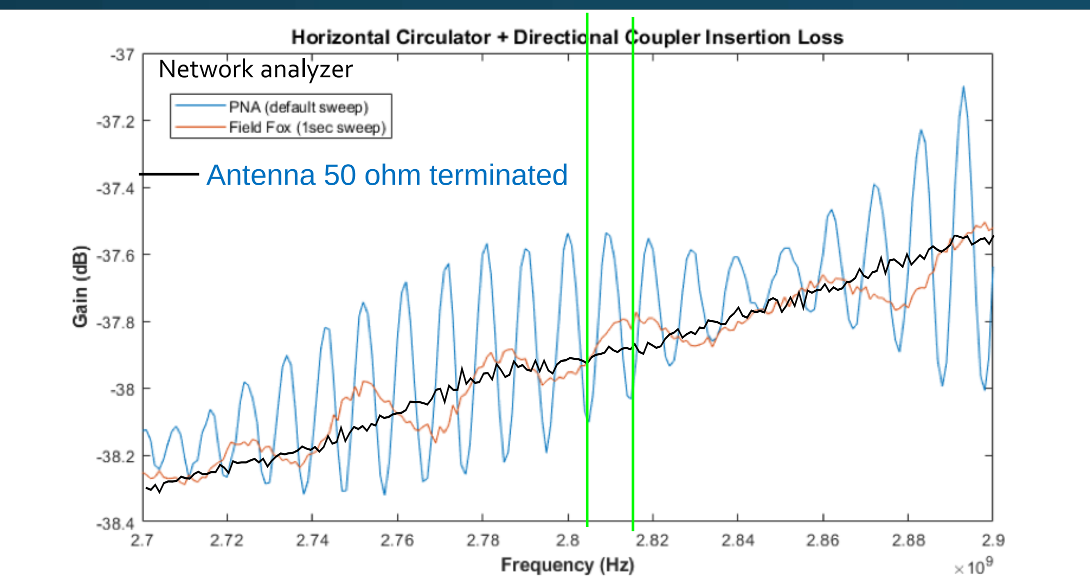
But Zdr bias varies very little!!

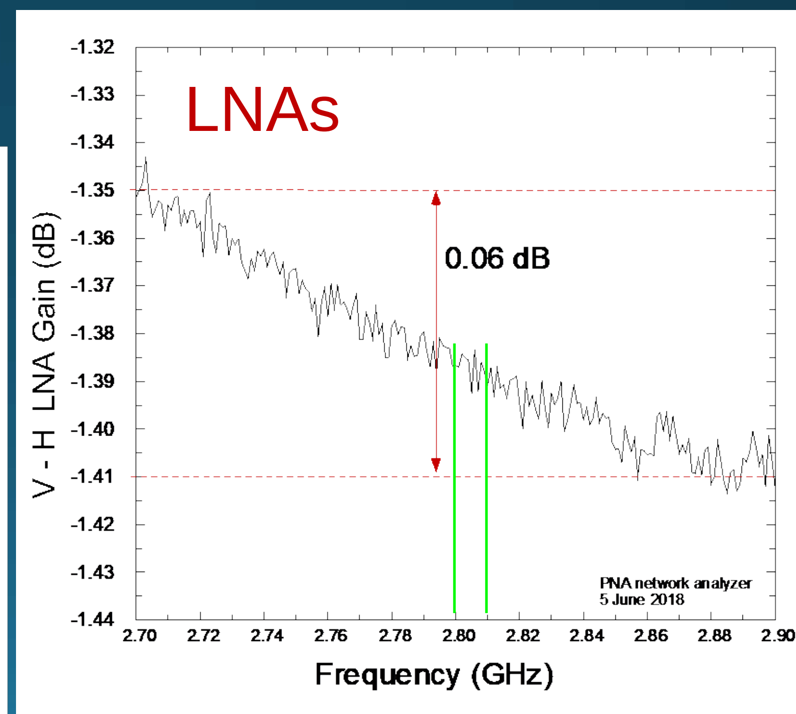


Differential Gain of RF Section



$$S_1 S_2 = \frac{(W_V G_V^A C_V^R LNA_V)^2}{(W_H G_H^A C_H^R LNA_H)^2}$$

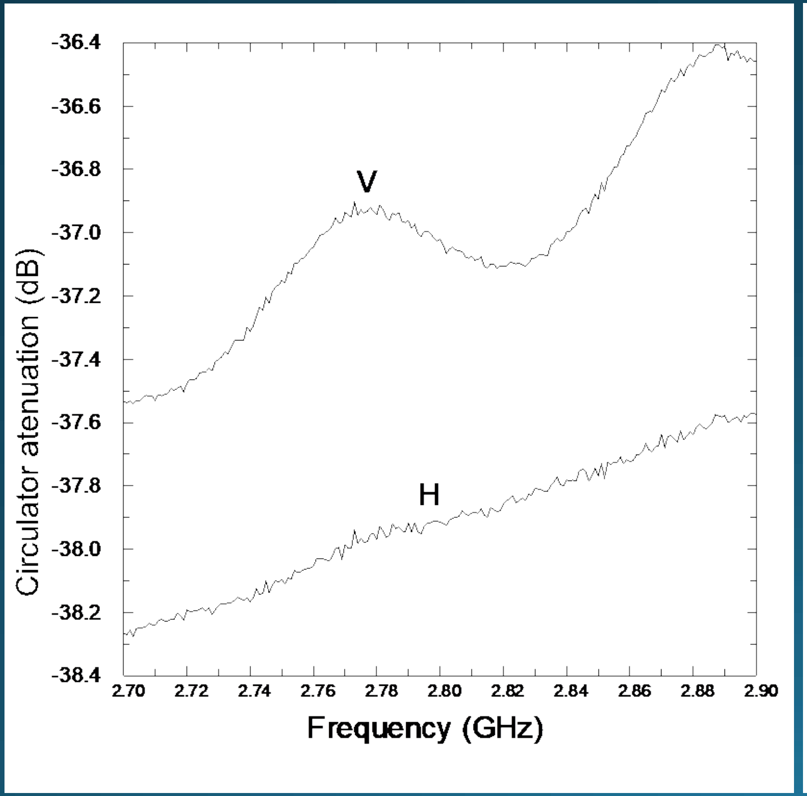




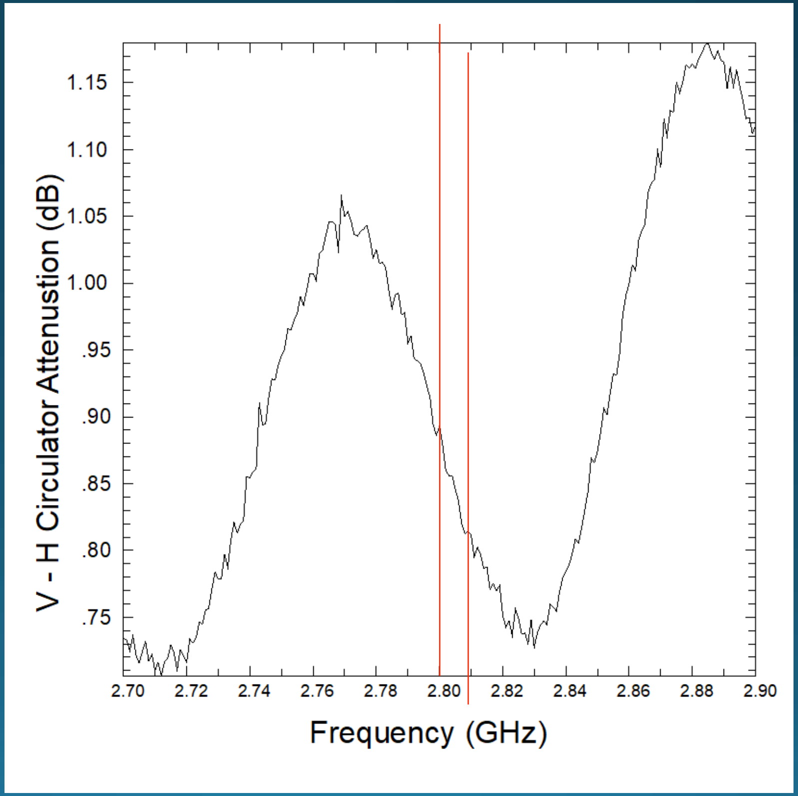
Likely that the RF diff. gain is cause the seen S1S2 frequency variation.

Circulator Attenuation

Wave guide to antenna terminated (50 ohms)

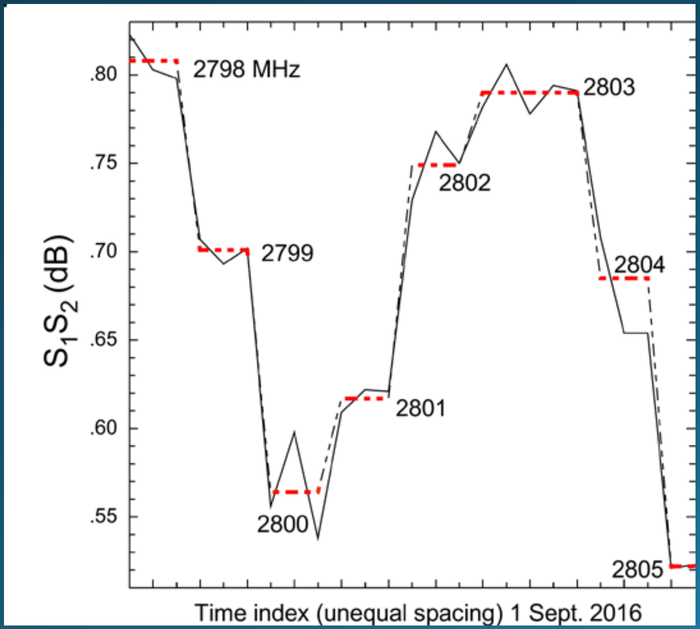


V-H Difference



Antenna Solar Diff Gain S1S2 Conclusion ????

- Good question
- LNAs aren't the source of differential gain change
- The circulators appears the likely source
- The measurements of the circulator with and with out antenna termination are very different.
- So antenna impedance is a function of frequency so that the gain is affected




THEATER
AN INCONVENIENT TRUTH
A REASSURING LIE
THE CHRISTIAN SCIENCE MONITOR
Bennett

ICPR Patterns

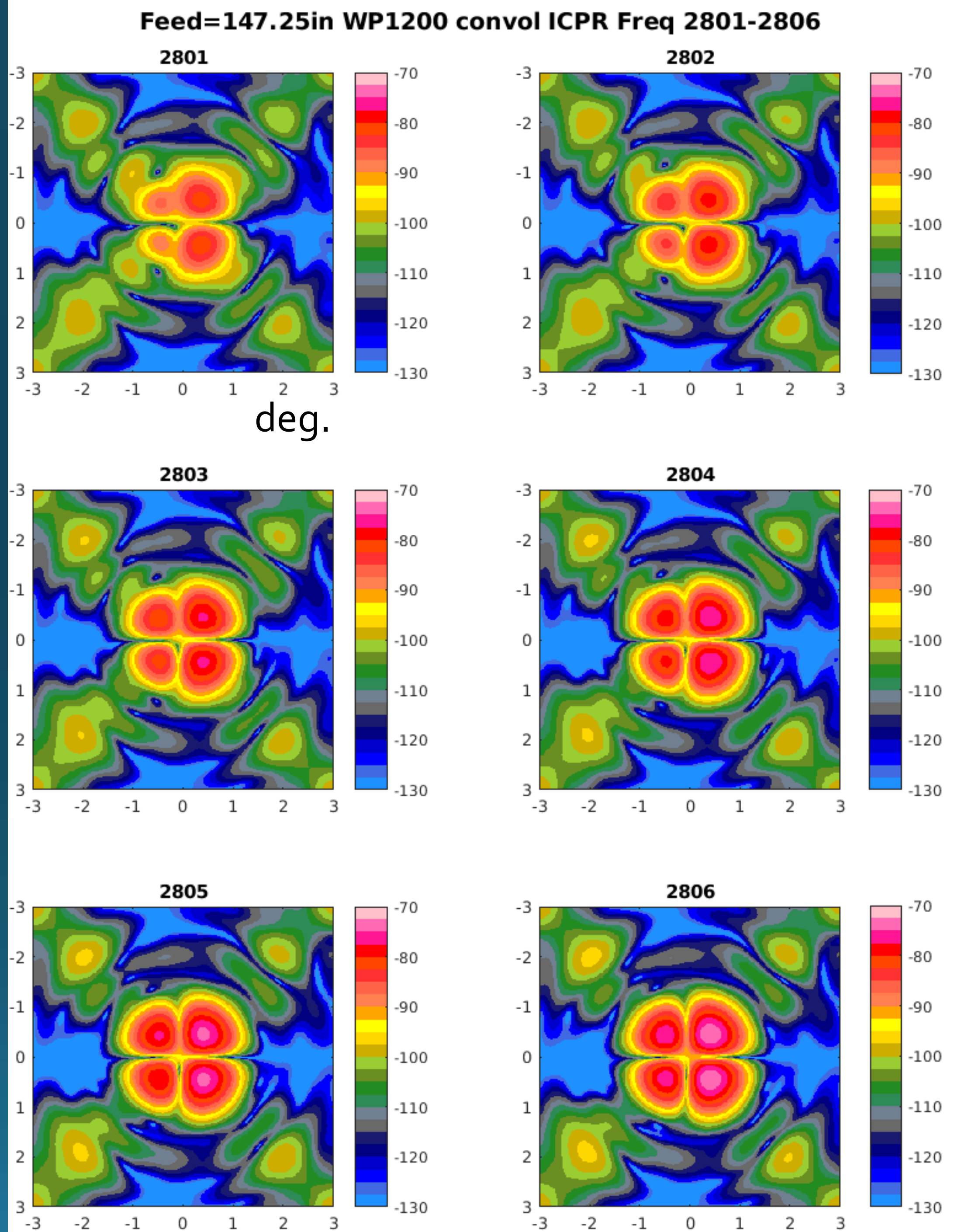
Integrated Cross-Polarization Ratio

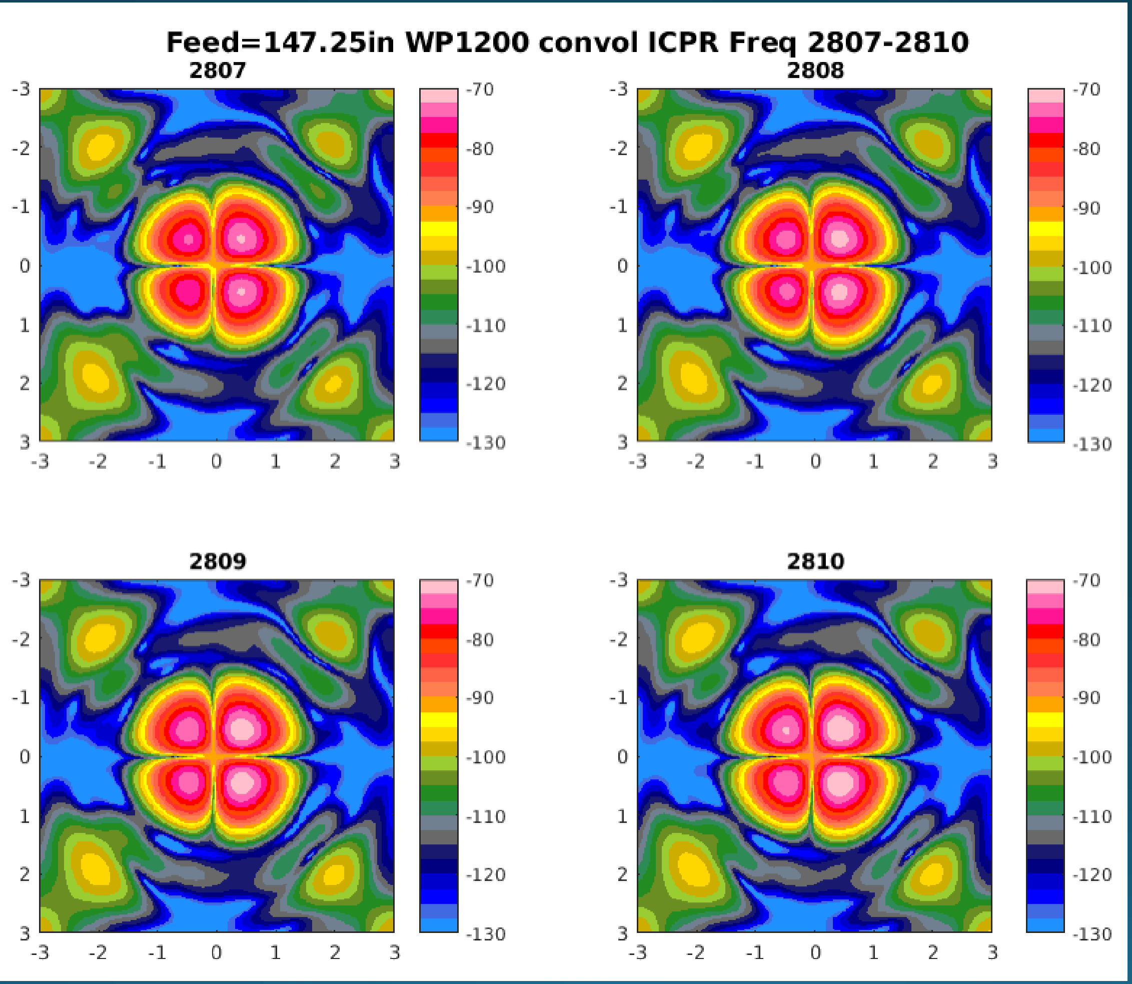
A measure of inter-channel isolation or polarization purity

$$\mathrm{ICPR} = \frac{\int |f_{HH} f_{VH} + f_{HV} f_{VV}|^2 \, d\Omega}{\int |f_{HH}^2 + f_{VV}^2|^2 \, d\Omega}$$

Wang and Chandrasekar, 2006, IEEE Transactions on Geoscience and Remote Sensing

"to limit Z_{dr} errors to +/- 0.2dB, -44dB isolation needed." (For SHV ops.)

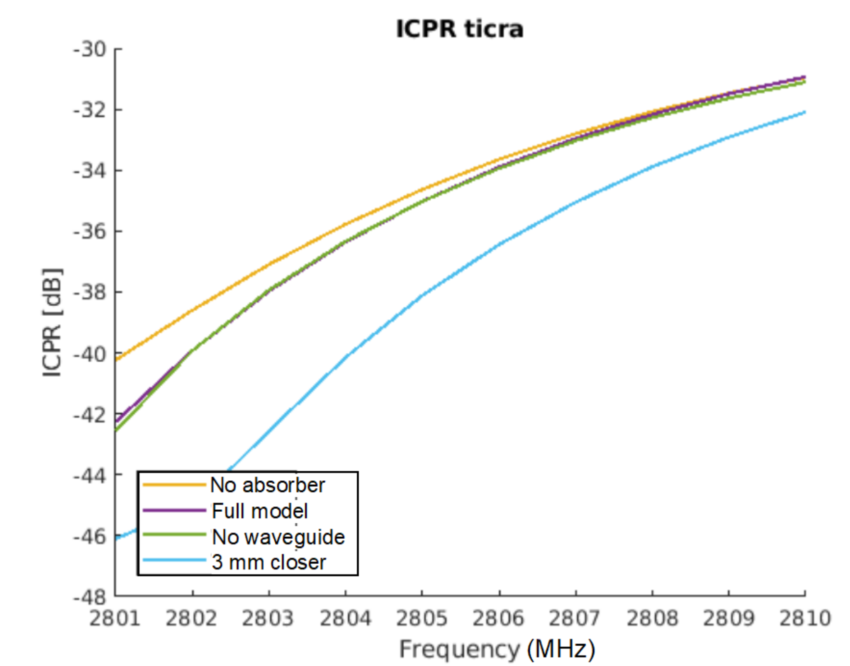




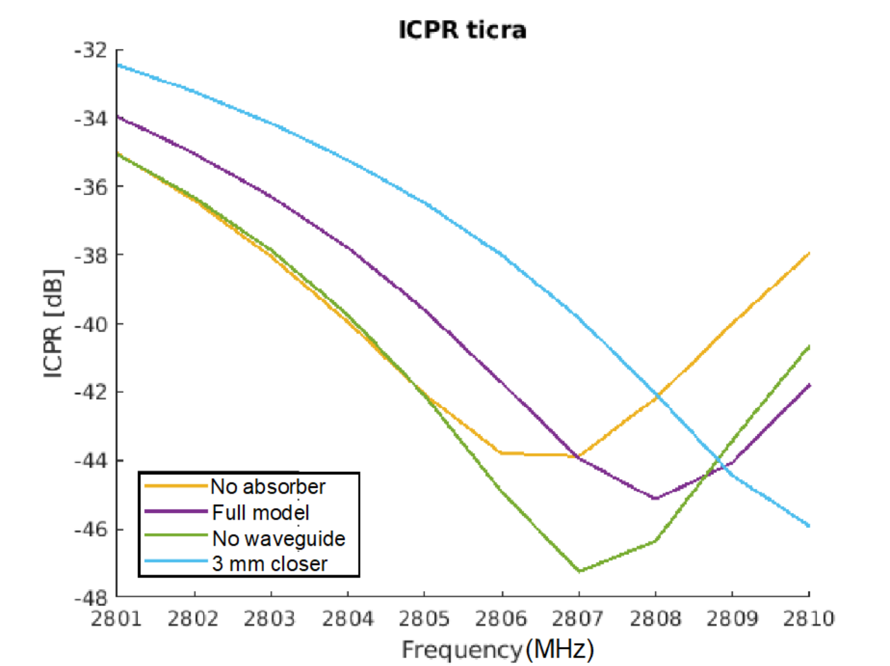
Feed=147.25in WP1200 convol ICPR Freq 2807-2810
2807
2808
2809
2810
-70
-80
-90
-100
-110
-120
-130

Integrated ICPR

Phase center at 149.5 in

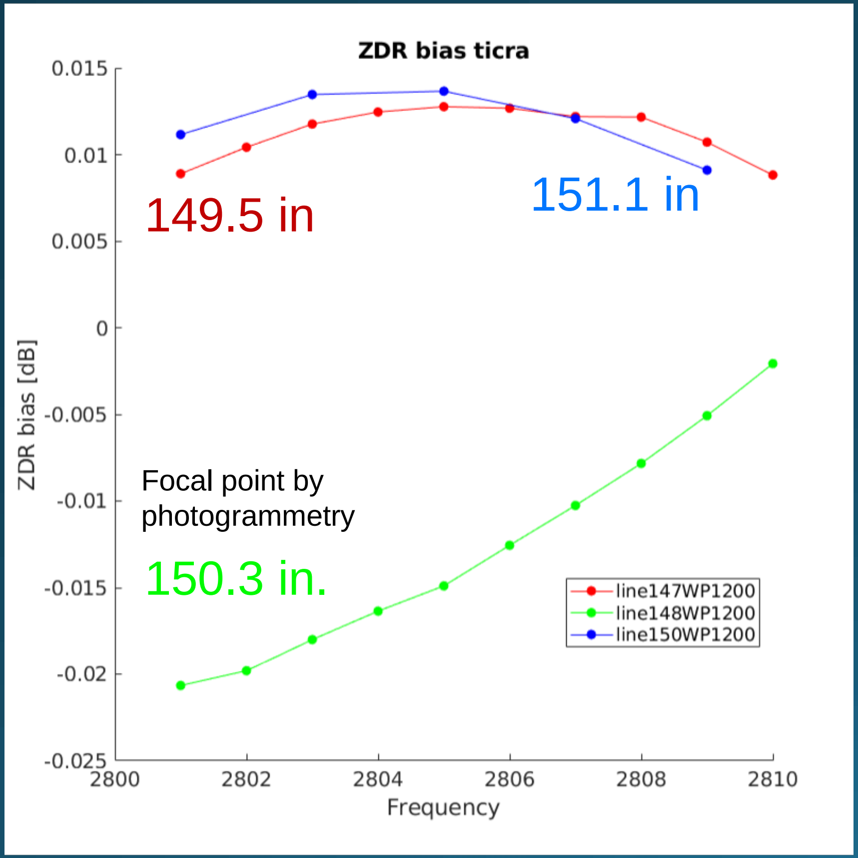


Phase center at 151.1 in

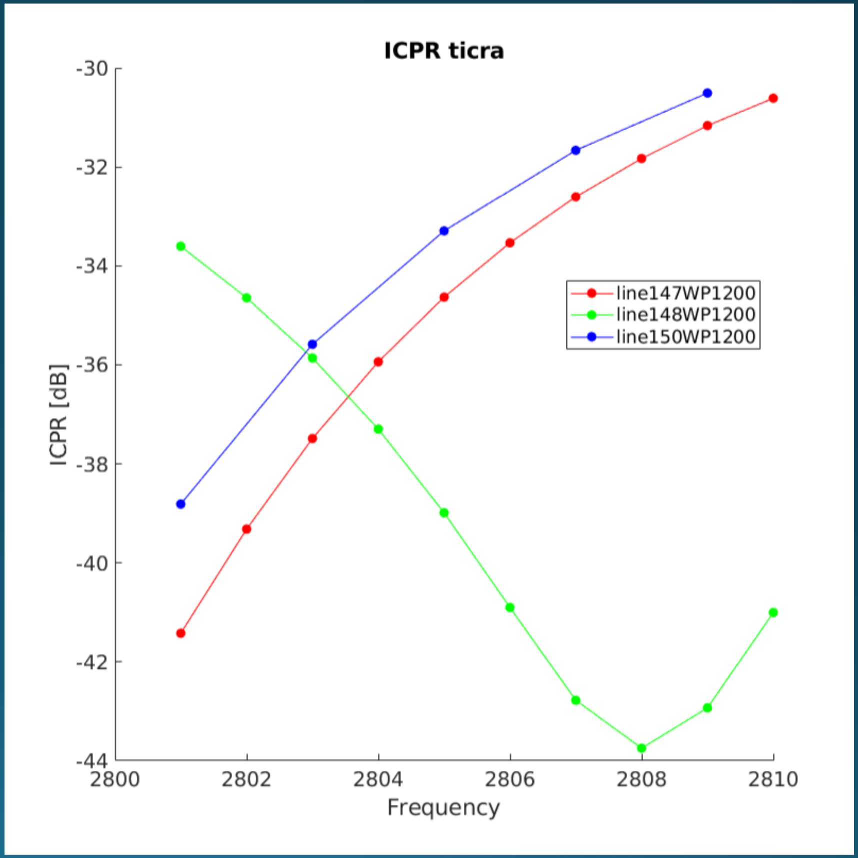


Full Model Comparison for 3 Phase Center Locations

Zdr Bias

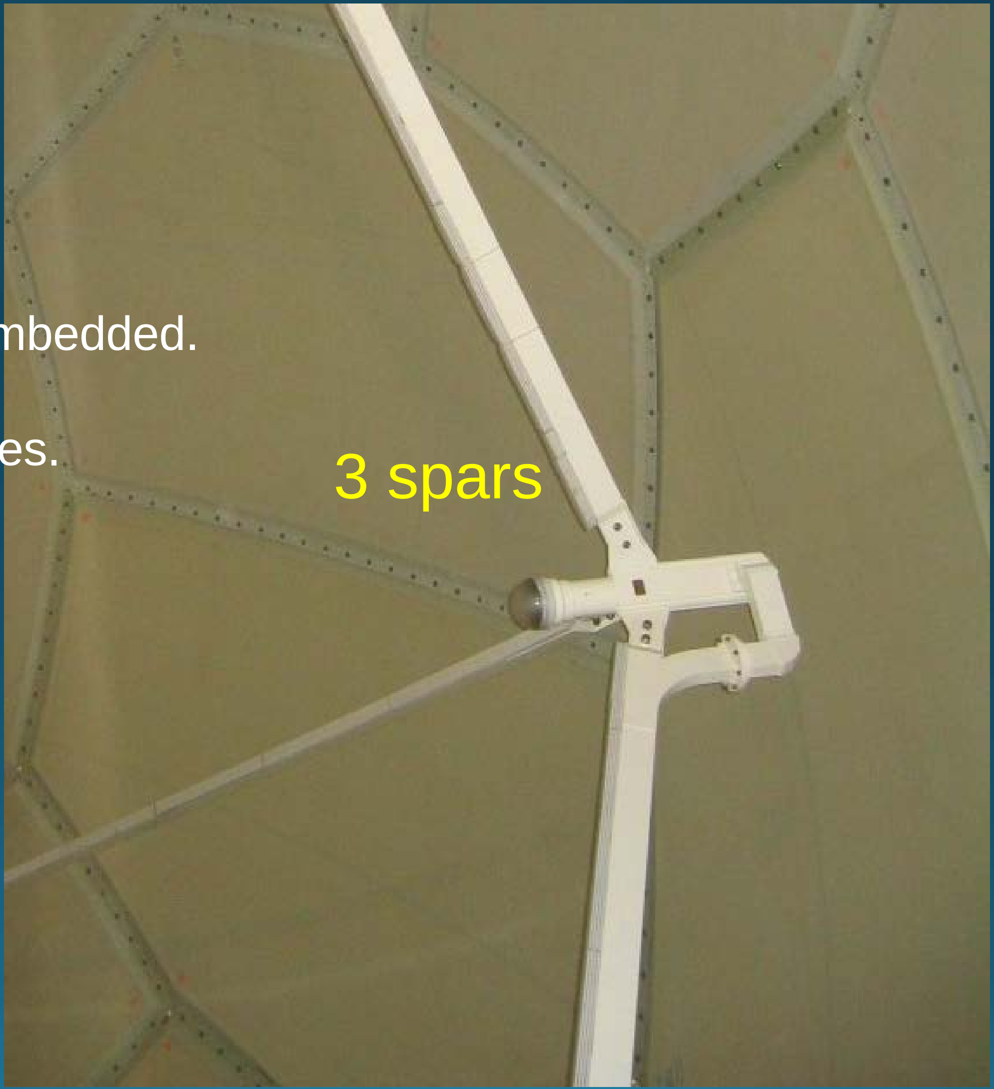


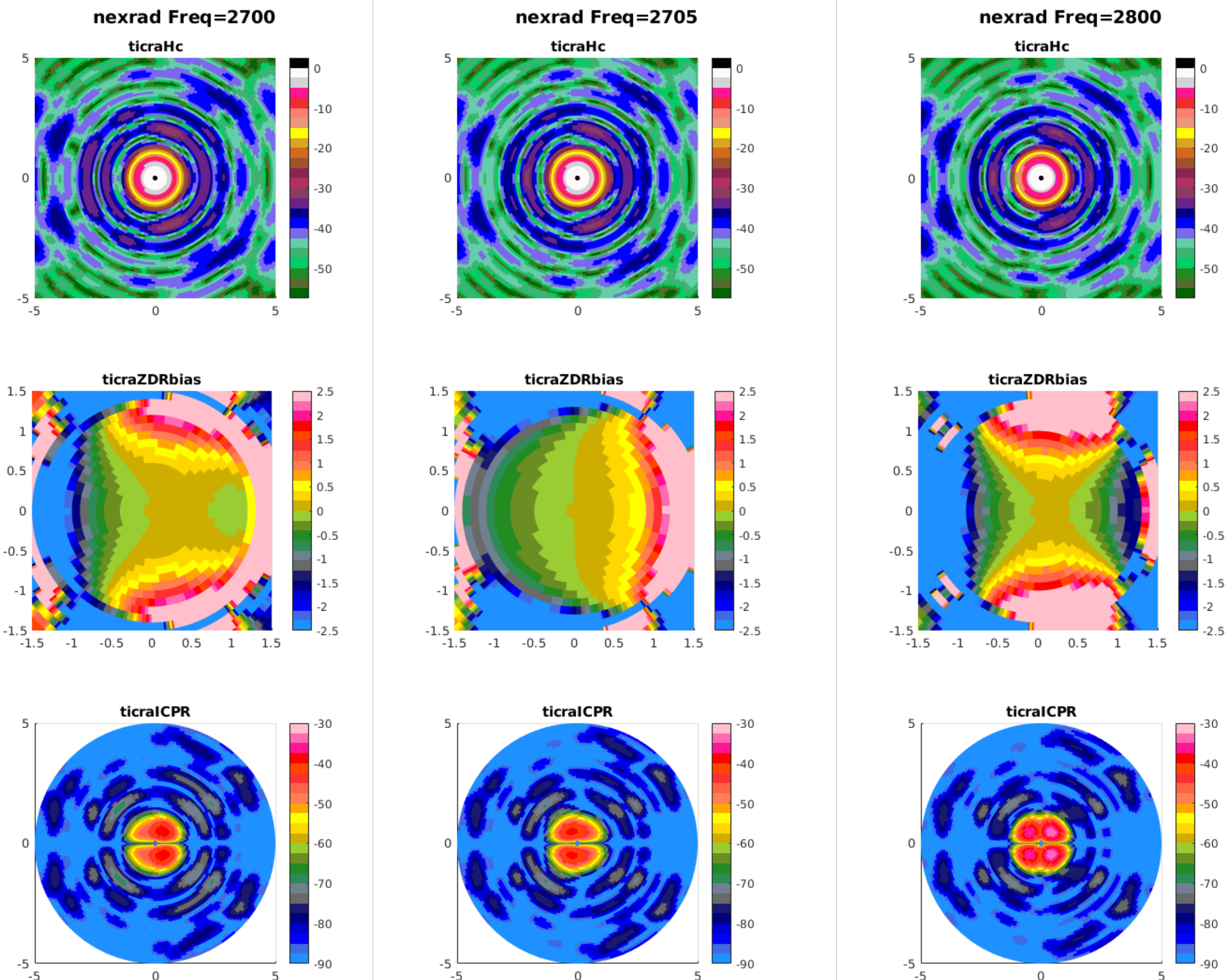
ICPR

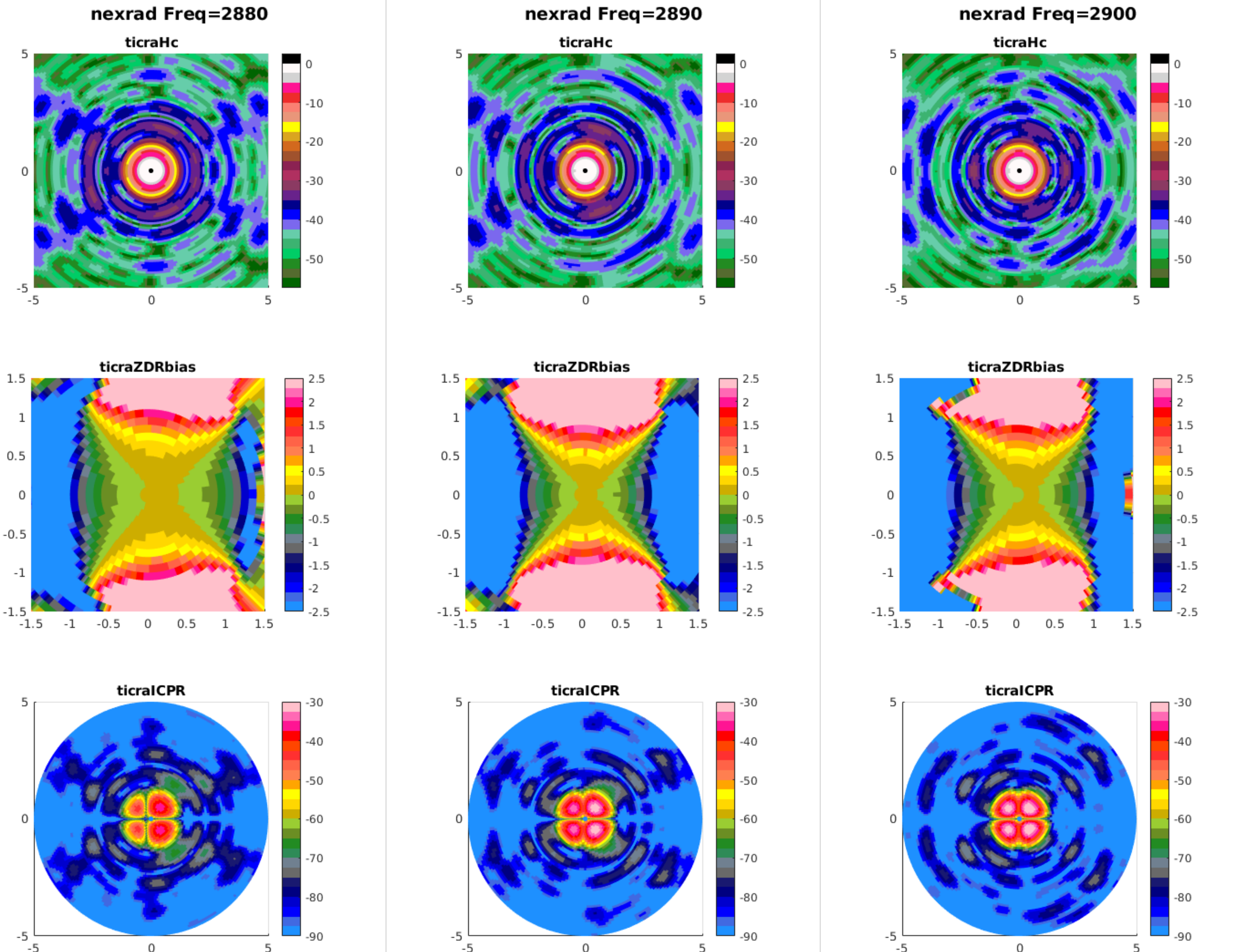


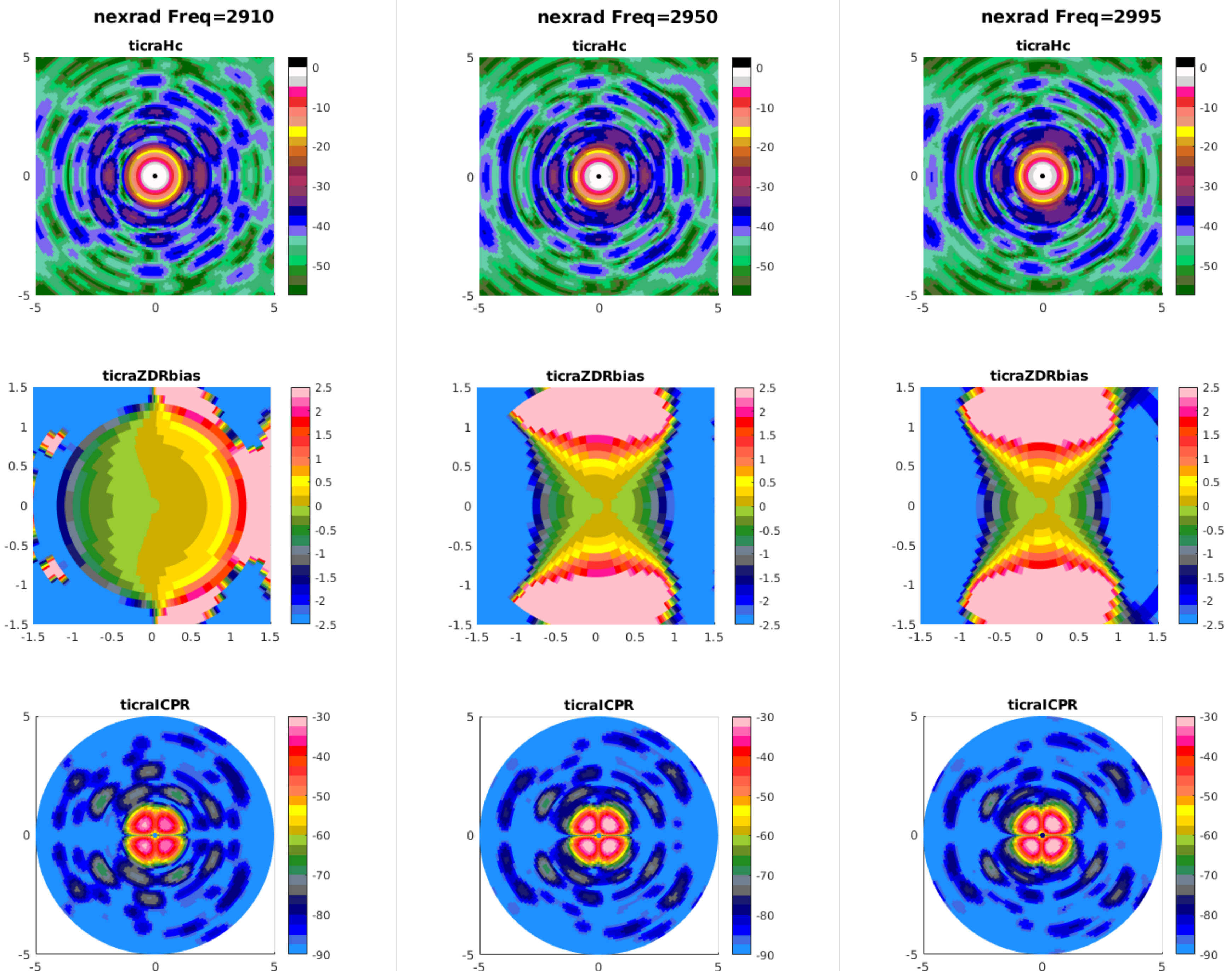
NEXRAD: Modeling the WSR-88DP

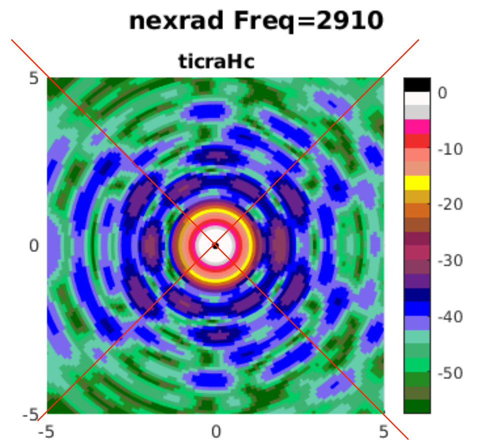
- Three spars with waveguide embedded.
- Absorber on spars.
- Spars at 0, 120 and 140 degrees.
- Cad drawing od feed horn.
- Did not model radome.



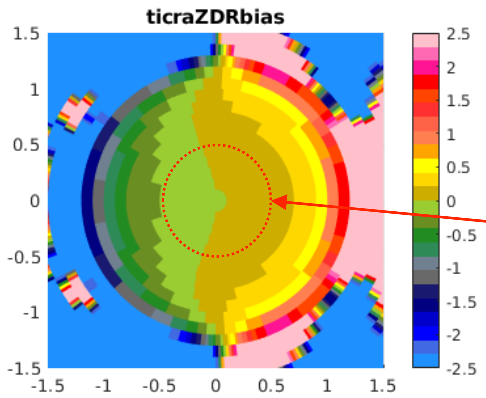

nexrad Freq=2700
nexrad Freq=2705
nexrad Freq=2800
ticraHc
ticraHc
ticraHc
ticraZDRbias
ticraZDRbias
ticraZDRbias
ticraICPR
ticraICPR
ticraICPR


nexrad Freq=2880
nexrad Freq=2890
nexrad Freq=2900
ticraHc
ticraZDRbias
ticraICPR


nexrad Freq=2910
nexrad Freq=2950
nexrad Freq=2995
ticraHc
ticraHc
ticraHc
ticraZDRbias
ticraZDRbias
ticraZDRbias
ticraICPR
ticraICPR
ticraICPR

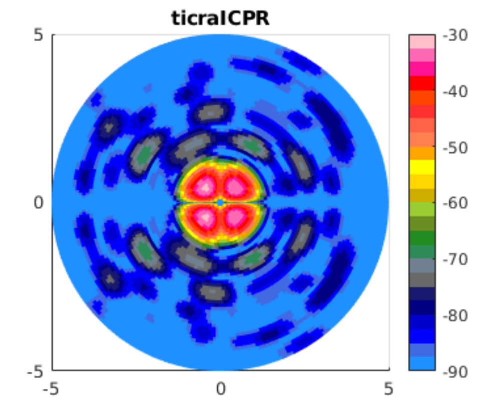


Side lobes are not highest along +/-=45 degree cuts



Zdr bias pattern can have gradients across it.
0.2 dB color steps.

1 degree solid angle

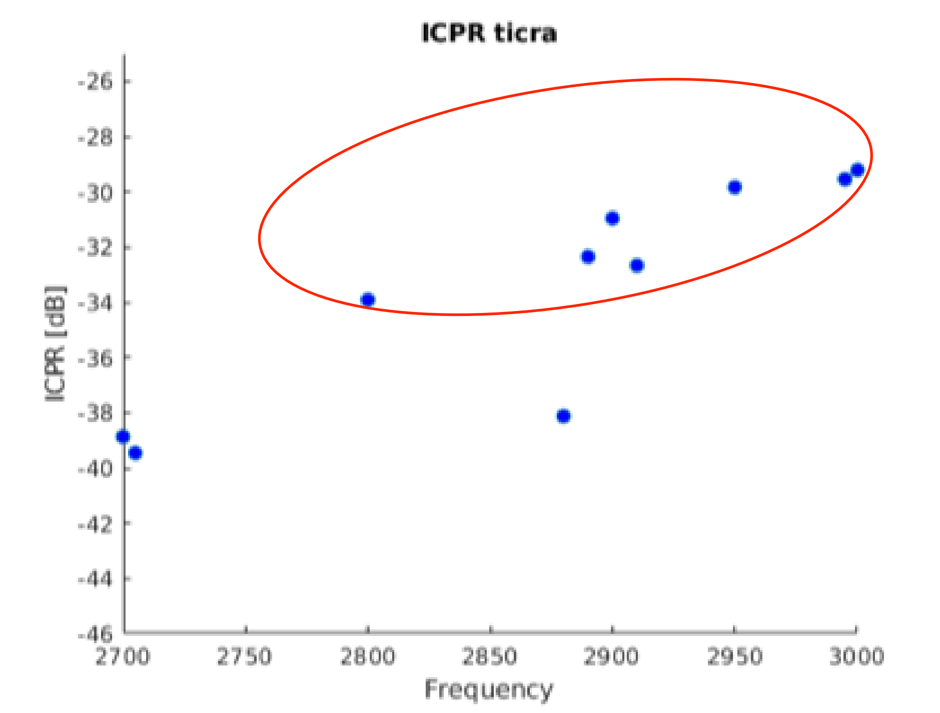


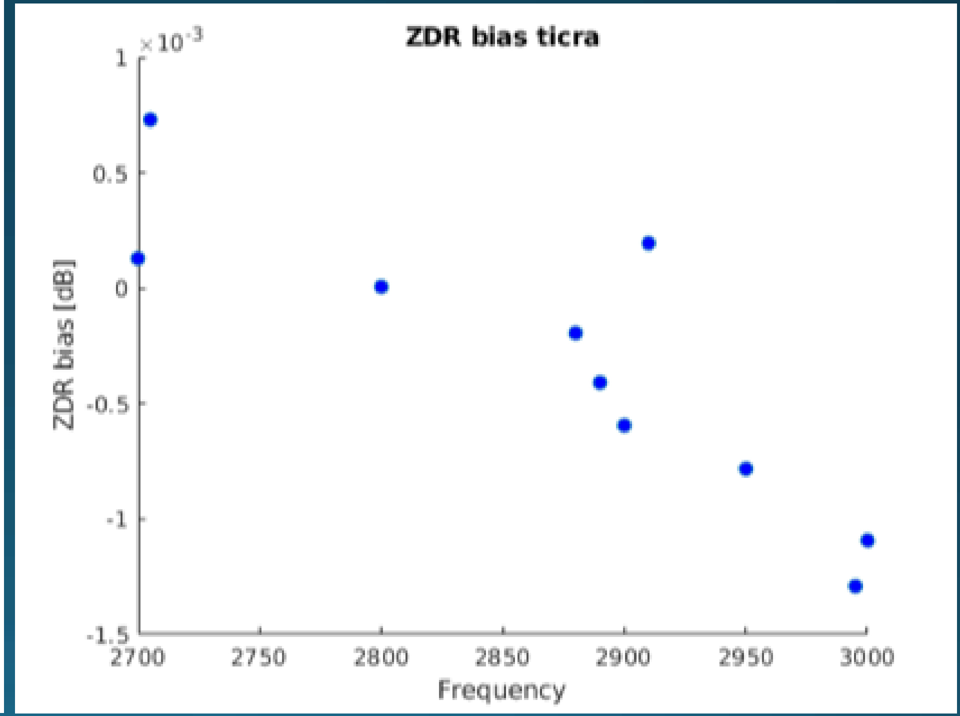
ICPR pattern looks similar to S-Pol 4 spar model data

WSR-88DP: Zdr Bias and ICPR

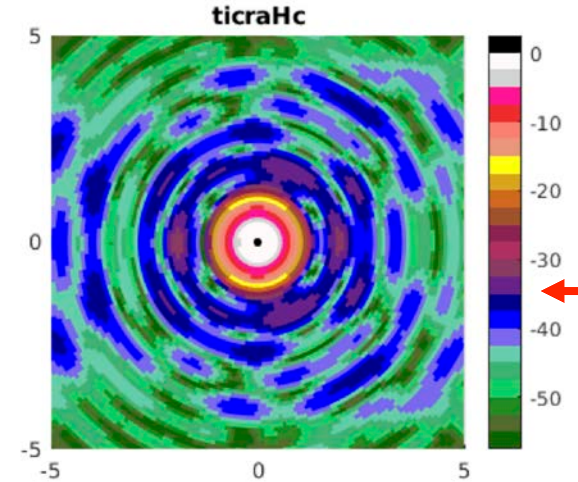
These higher values indicate cross coupling could be a problem for higher phidp accumulations

Zdr offset is a function of frequency but will be corrected by Zdr calibrations



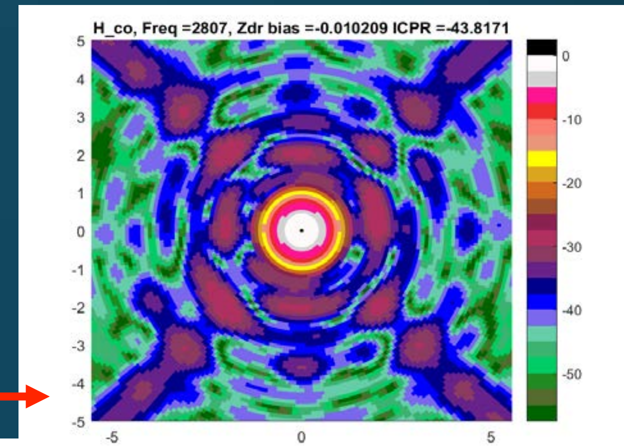


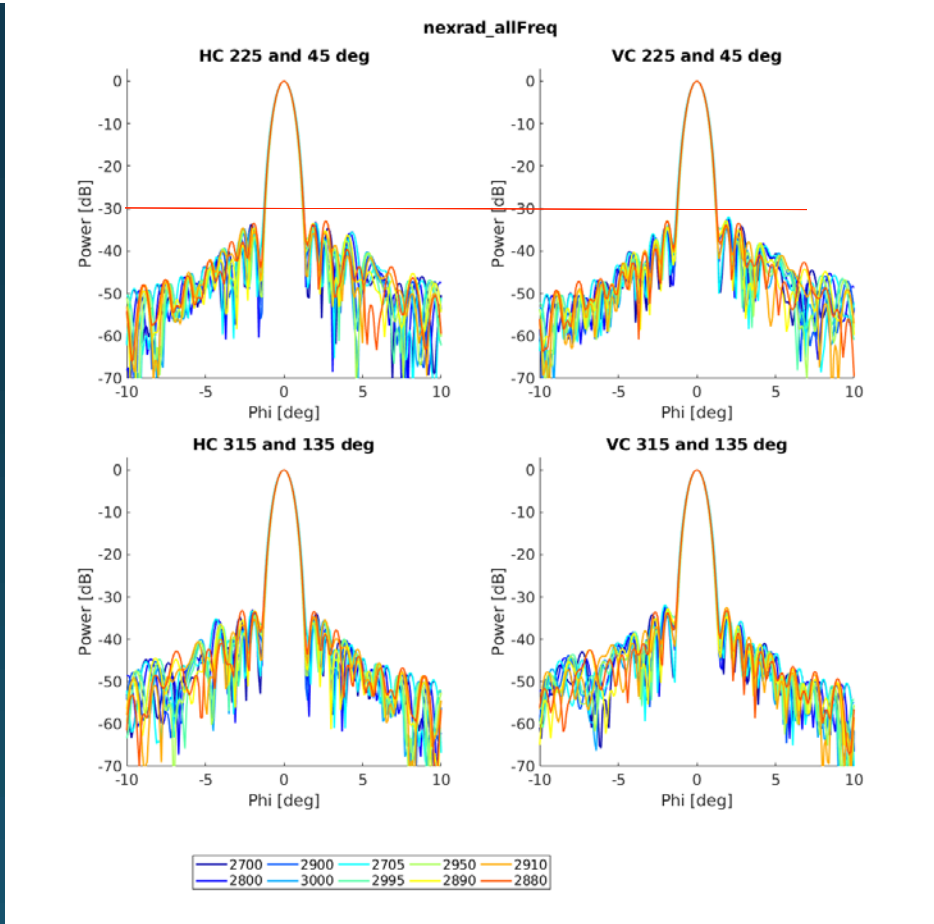
The +/- 45 Degree Antenna Pattern Cuts

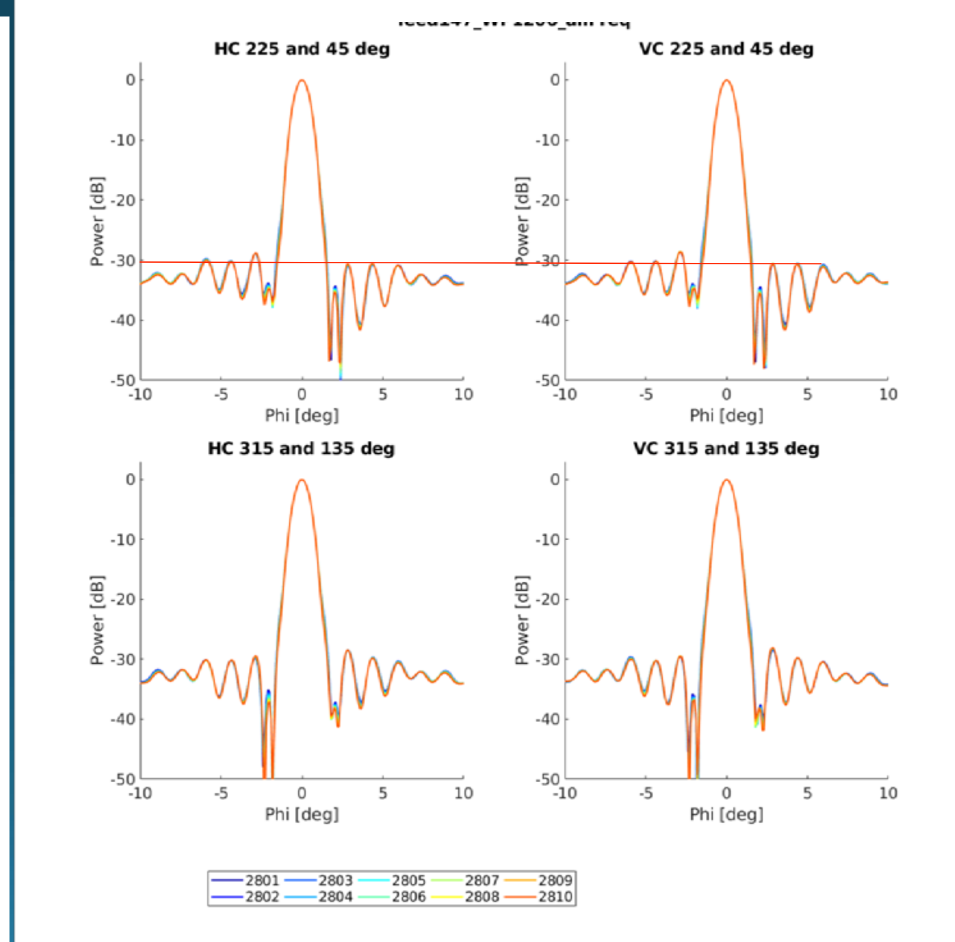


WSR-88DP, 3 spar

S-Pol, 4 spar







Observations

- S_1S_2 (Zdr) antenna pattern SHAPE changes for both temperature and frequency changes
- GRASP MODEL: predicts Zdr shape changes but, S1S2 differential gain is not predicted
  - *RF component's differential gain causes the observed frequency dependent dif. gain.*
- EXPERIMENTAL: S_1S_2 integrated does change substantially for changes in temperature: ~0.01dB/C
- Expansion/contraction of the entire antenna structure causes both Zdr antenna pattern shape as well as Zdr bias to change.
- ICPR is a complicated function of frequency and antenna topology

Hubbert, J. C., 2017: Differential reflectivity calibration and antenna temperature. J. Atmos. Oceanic Technol., https://doi.org/10.1175/JTECH-D-16-0218.1

ICPR: Cross Coupling

- Very sensitive function of frequency
- Zdr bias for simultaneous H and V transmit radars is a function of this cross coupling (channel isolation)
- To keep Zdr bias to with in 0.2dB, isolation should be -44dB (Wang and Chandrasekar 2006)
- ICPR is a sensitive function of phase center location

- WP1100: Geometry including 4 struts and 2 waveguides
- WP1200: Geometry including 4 struts with absorbers and 2 waveguides
- WP1300: Geometry including 4 struts with absorbers
- WP1400: Geometry including 4 struts with absorbers and 2 waveguides and feed moved 3 mm closer to the reflector