DIFFERENTIAL REFLECTIVITY CALIBRATION for NEXRAD

NEXRAD TAC MEETING
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NCAR's Z_{dr} CALIBRATION TASK

- Evaluate the various methods for Zdr calibration
  - i.e., evaluate the uncertainty of the methods
- Recommend Z_{dr} calibration procedures for NEXRAD radars

Z_{dr} Calibration Methods

- Engineering calibration
  - Use test equipment (power sources & meters)
- Crosspolar power technique
  - Use external targets (sun, clutter, precipitation)
- Vertical pointing data in light rain

Deployment
Development
Data Services

Z_{dr} Calibration Issues

- Can Zdr be calibrated to 0.1 dB for NEXRAD?
- Since simultaneous H&V mode, two copolar receivers necessary (added complexity)
- WSR-88D's can not point vertically (60 deg. max)
- Calibration technique should be easily executed by radar technicians or automated

UNCERTAINTY

Uncertainty represents the standard deviation of a set of measurements and is usually quantified by repetition of measurements under controlled test conditions

Errors:

1) Systematic

2) Random

$$Z_{dr} = Z_{dr}^{m} \;+/-\; \delta \;\; (0.1\text{dB})$$

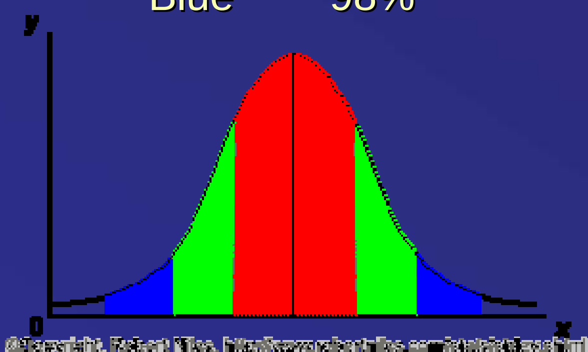
Fractional uncertainty

STD/mean

Percent: 10^(0.1/10) ➡ 2.3%

Coverage

Red	68%
Green	95%
Blue	98%



Normal

Engineering Calibration Method

- Break calibration task into static and dynamic components
  - Static components are waveguide, radar antenna and dish
  - Dynamic components are the receiver chains, i.e., from LNA inputs to I&Q samples
- Measure the static differential losses with the sun, noise sources, power meters, etc.
- Monitor the dynamic differential gain by inserting test pulses at the end of each range

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S-Pol and CHILL

- Both use this method but routinely find that there still is a Zdr bias of a few tenths of a dB
- Final Zdr calibration achieved by using vertical pointing data
- Reason for this discrepancy is assumed to be limited accuracy of measurements
  - Can they be made more accurate?

RF Power Measurements

- Consider wave guide couplers at S-Band
- Typical specifications are attenuation factor +/- 0.25 dB!
  - Impedance mismatch between coupler and wave guide, and between power meter and coupler
- It is *very difficult* to know with in a tenth of a dB how much signal actually is present in a wave guide

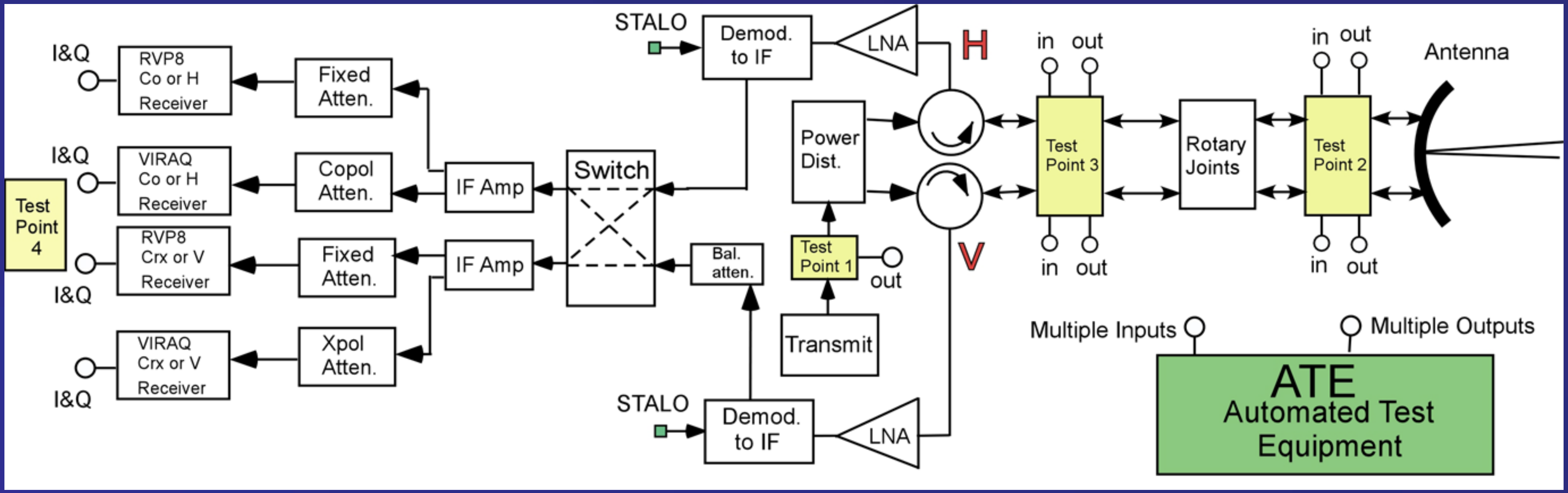
Essence of Crosspolar Power Technique

Scattering Matrix: $E_r = \begin{pmatrix} S_{hh} & S_{hv} \\ S_{vh} & S_{vv} \end{pmatrix} E_i$

Reciprocity: $S_{hv} = S_{vh}$

- If crosspolar powers are not equal, then there is a differential path imbalance
- Note that the transmit power and path are included

S-Pol Block Diagram



ATE:Automated Test Equipment Subsystem

PC running Lab View

- Power meter
- Programmable signal generator
- Programmable attenuator
- RF Matrix Switch
- Temperature sensors
- Noise sources
- 10 micro. sec. delay line
- LAN

Crosspolar Power Technique

Z_{dr} calibration equation becomes:

$$Z_{dr} = Z_{dr}^{m} S_1 S_2 \frac{\overline{R_{HVHV}}}{\overline{R_{VHVH}}}$$

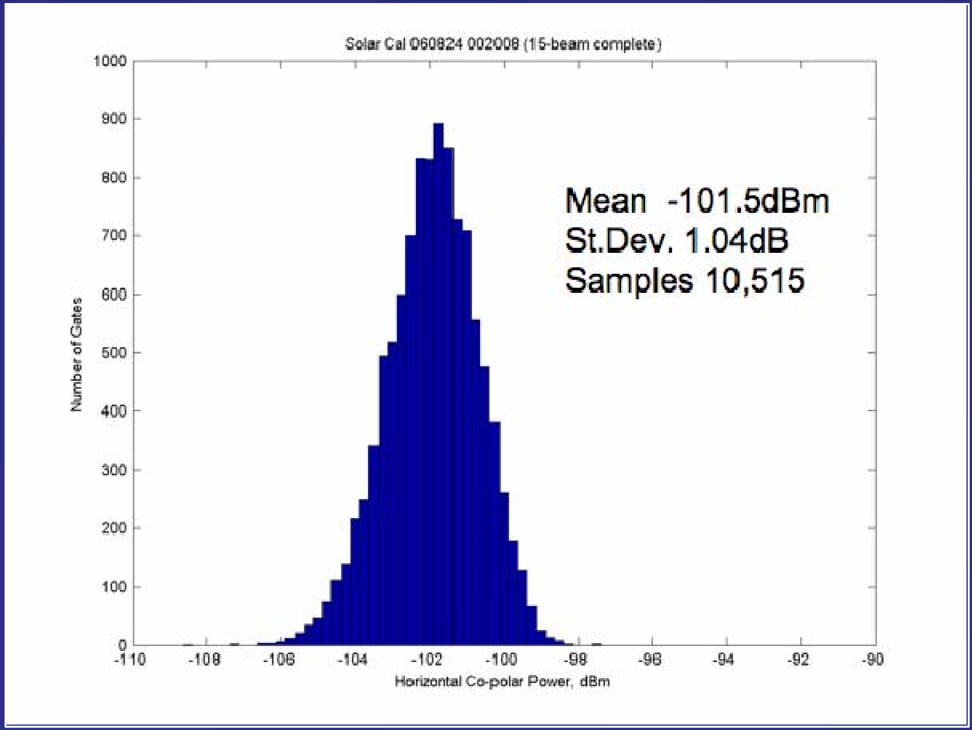
Average crosspolar powers

Ratios of sun powers

Where S_1, S_2 are the “copolar” and “crosspolar” sun calibration ratio numbers

(see Hubbert et al., Studies of the Polarimetric Covariance Matrix: Part I Calibration Methodology, JTECH, 2003)

Sun Measurements



If 0.01 dB fractional standard deviation is desired, then about 13,800 samples should be used to compute the overall mean. This is easily accomplished.

Sun Measurements

- Scan the sun passively
- Scan parameters
  - 8 deg. By 4 deg. Box
  - 1 deg./ sec
  - 0.2 deg. elevation steps
- Use powers > -102 dBm
- Calculate mean of from 3 highest power cuts
  - Use 5 “beams” and 700 gates with 64 samples per gate
- Calculate 4 channel powers U1, U2, U3, U4 and the ratios S1=U1/U2, S2 = U3/U4

Sun Measurements

On 8 August 10 consecutive box sun scans made

The calculated numbers are (linear scale)

0.7760	0.7789	0.7854	0.7773	0.7843
0.7713	0.7795	0.7745	0.7812	0.7767

The mean is 0.7885 with a standard deviation of 0.0041.

The fractional standard deviation is 0.023dB

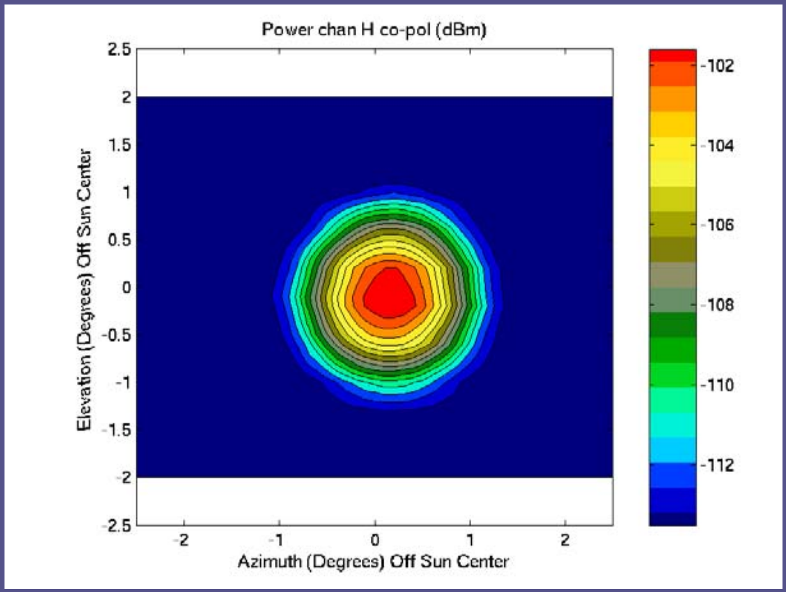
The 2 sigma uncertainty of 0.7885 is:

-1.032 +/- 0.007 dB

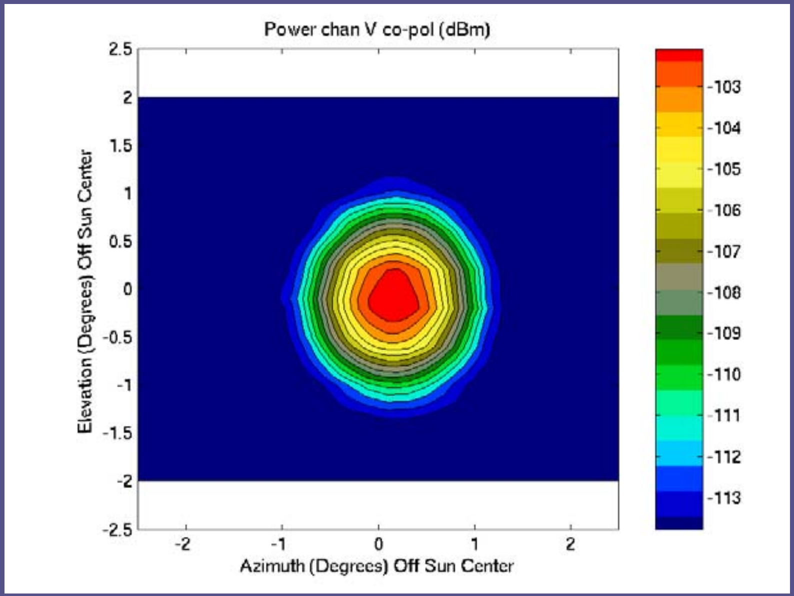
mean uncertainty

S-Pol Sun Antenna Patterns

H Antenna pattern

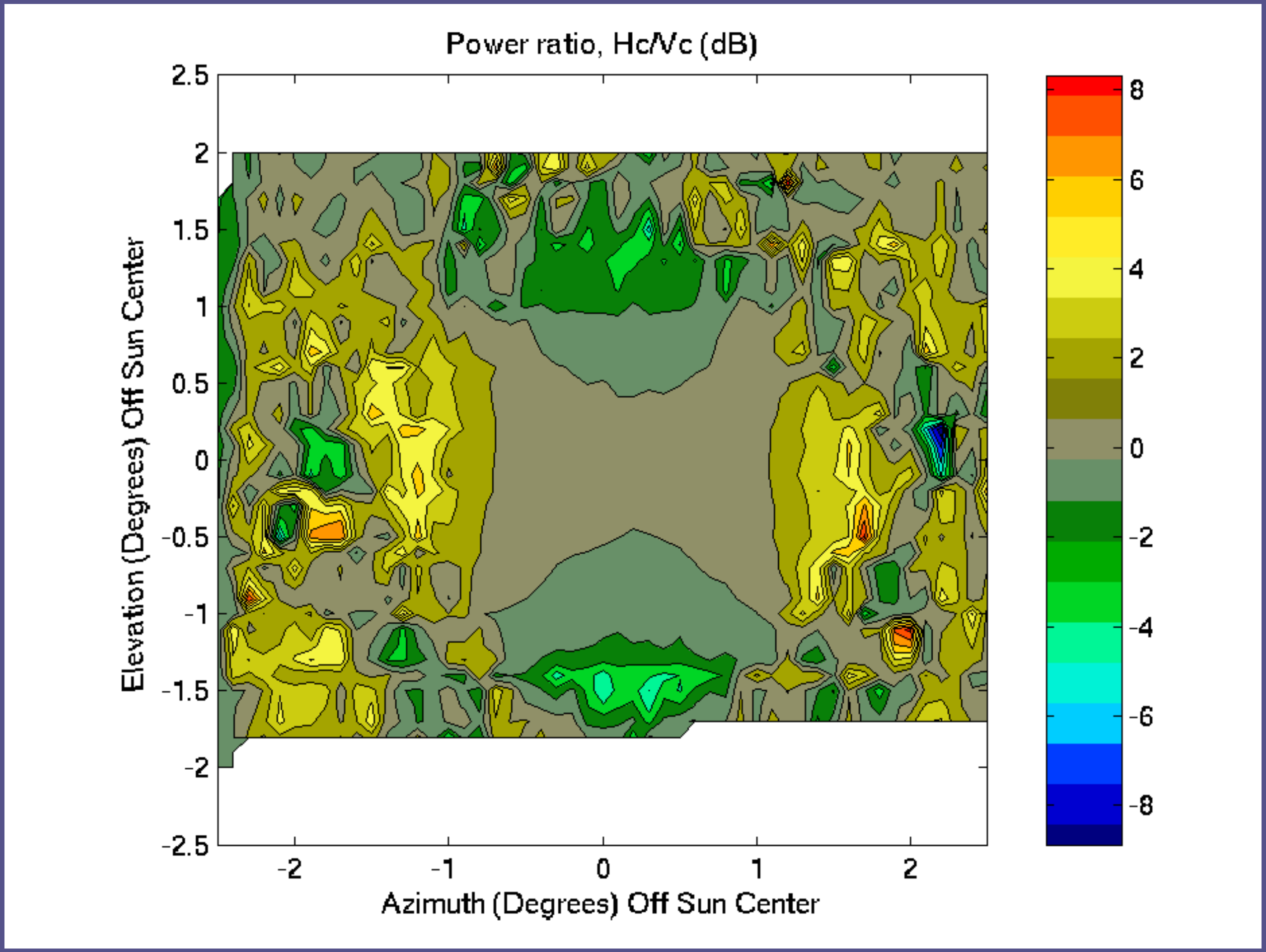


V Antenna pattern

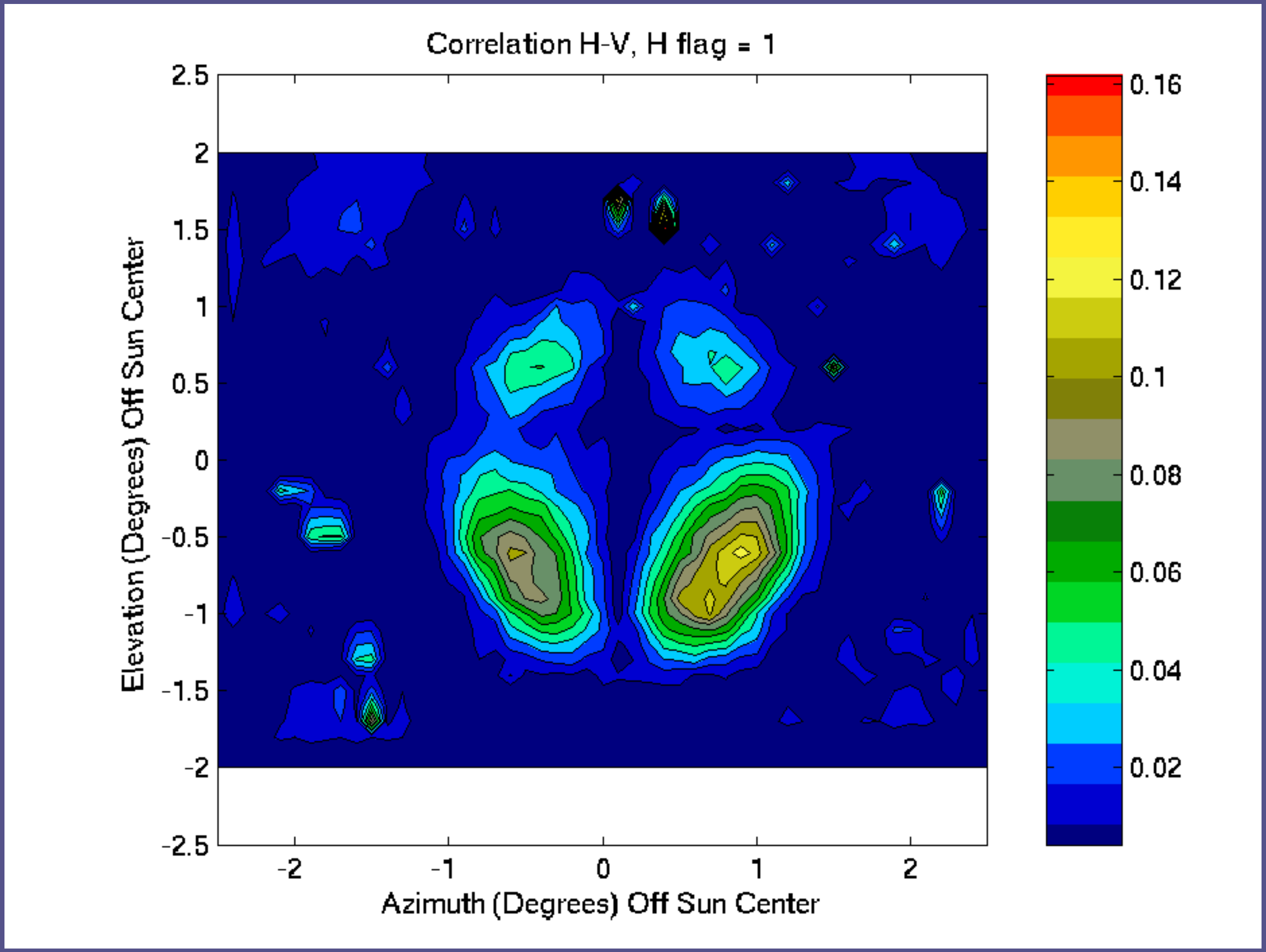


- Scan the sun slowly
- Correct for sun movement
- Correct for elevation angle distortion
- Subtract noise power

Difference Between H and V



H to V Correlation Coefficient



Vertical Pointing Measurements

- Average Zdr data over 360 degrees (31 August 2006)
  - Use data at > 4 km to avoid differential TR tube recovery

- Six vertical pointing “volume” scans
- Data in 1 km bins from 4 to 9 km yielding 30 Zdr bias estimates.
- Calculate mean and standard deviation:

  m = 0.712 dB STD = 0.019 dB
- This gives a 2 sigma uncertainty of 0.007 dB

  i.e., Zdr bias = 0.712 dB = +/- 0.007 dB

Crosspolar Power Measurements

Similar analysis can be done for crosspolar power measurements:

- Scan rate of 12 deg/sec
- 14 PPI scans, 64 point intergration

-0.312 -0.335 -0.326 -0.341 -0.347 -0.357 -0.347
-0.263 -0.276 -0.304 -0.337 -0.319 -0.343 -0.319 (dB)

The mean is -.323 dB and the fractional standard deviation is .026 dB
The mean of the numbers above, however, has a *two standard deviation* fractional uncertainty of 0.014 dB.

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NEXRAD Crosspolar Power Measurements

- NEXRAD will not have near simultaneous crosspolar power measurement
- But can use slow mechanical switches to make both crosspolar power measurements
- Since ground clutter is stationary, measuring ground clutter by alternating H and V power transmission on a PPI to PPI basis should preserve $P_{xh}=P_{xv}$
    - Need indexed beams!

NEXRAD Crosspolar Power Measurements

- Data was gathered first in fast alternating H and V mode.
- Shortly after data was gathered in transmit H only followed by transmit V only mode
- The average crosspolar ratios were calculated:
  - Pxh/Pxv = -0.404 +/- 0.0018 dB for fast switch mode
  - Pxh/Pxv = -0.373 +/- 0.032 dB for the slow switch mode.
    - 2 sigma coverage
    - 14 PPI scans used at 6 deg./sec
  - These results suggest that the crosspolar power Zdr calibration technique is amenable to NEXRAD

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Vertical Pointing Technique
versus
Crosspolar Power Technique

- 31 August 2006 data set
- Vertical pointing Zdr bias: 0.712 dB
- S_1S_2 sun ratio product: -1.051 dB
- P_{xh}/P_{xv} crosspolar power ratio: -.323 dB
- RESULT: -.323 - (- 1.051)= .728 dB

Zdr bias: VP 0.712 dB +/- 0.007 dB
CP 0.728 dB +/- 0.017 dB

Conclusions

- The sun power can be estimated to well within the desired 0.1 dB uncertainty
- The crosspolar power ratio can be estimated to well within the desired 0.1 dB uncertainty
- Ground clutter can be used in the estimation of the crosspolar power method Zdr bias
- A slow alternating switch can be used to collect both needed crosspolar powers
- Sun scan derived H and V antenna patterns should be calculated for verification of the NEXRAD antenna patterns
- Full evaluation of the engineering calibration method awaits the completion of the ATE
    - Will need, however, to account for impedance mismatches
- The dynamic calibration aspect needs to be investigated

Thank You for Your Attention

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