Calibrating differential reflectivity on the WSR-88D

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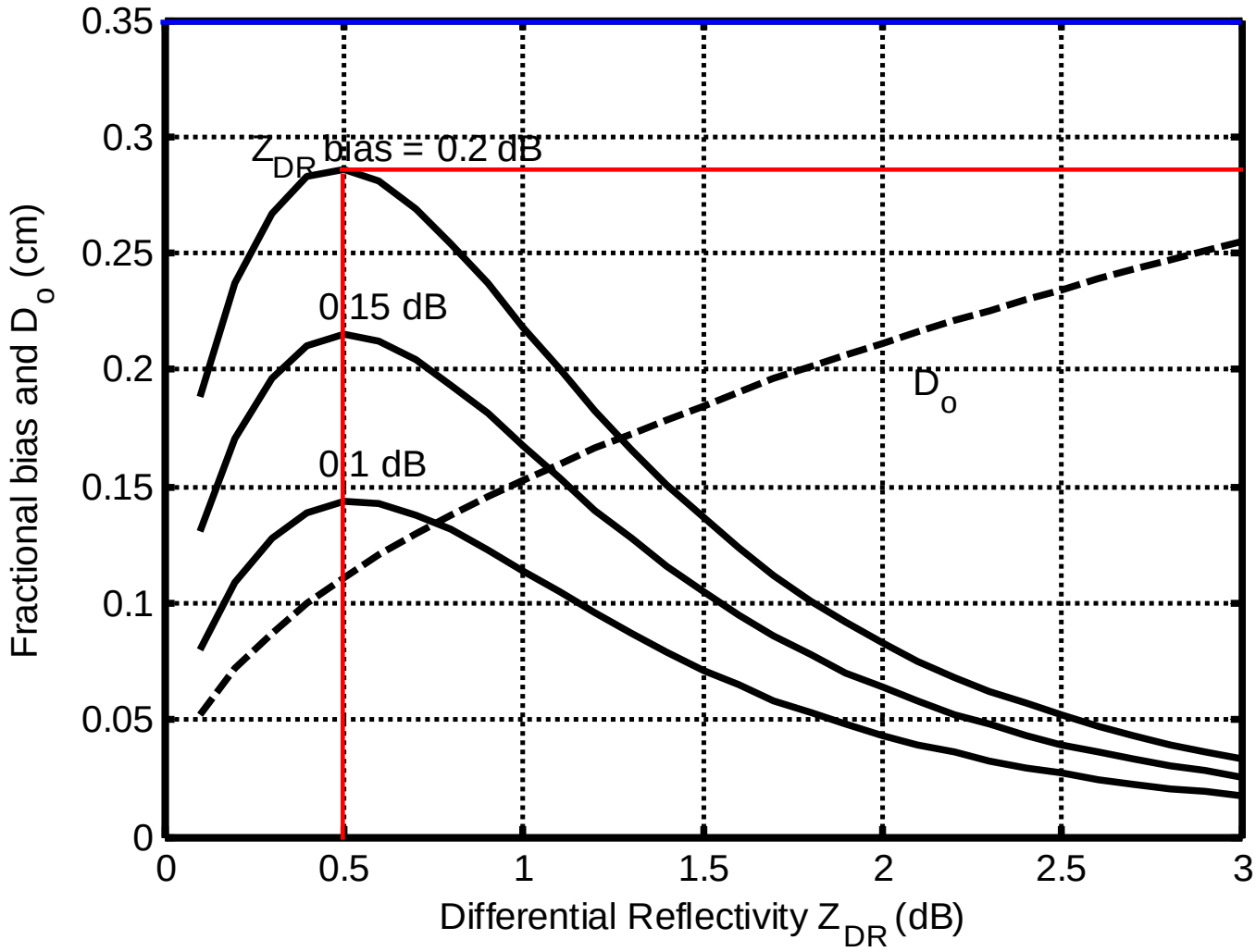
- Effects of Z_{DR} bias
  - On rainfall measurements
  - On classification of hydrometeors
- Calibration Procedure
  - Version I: Accounting for all links in the transmitter and receiver paths
  - Version II: Ignoring part of the transmitter path (waveguides to outside of radome)

Effects of bias on Rainfall Measurements

RMS error of Best R(Z) = 0.35%

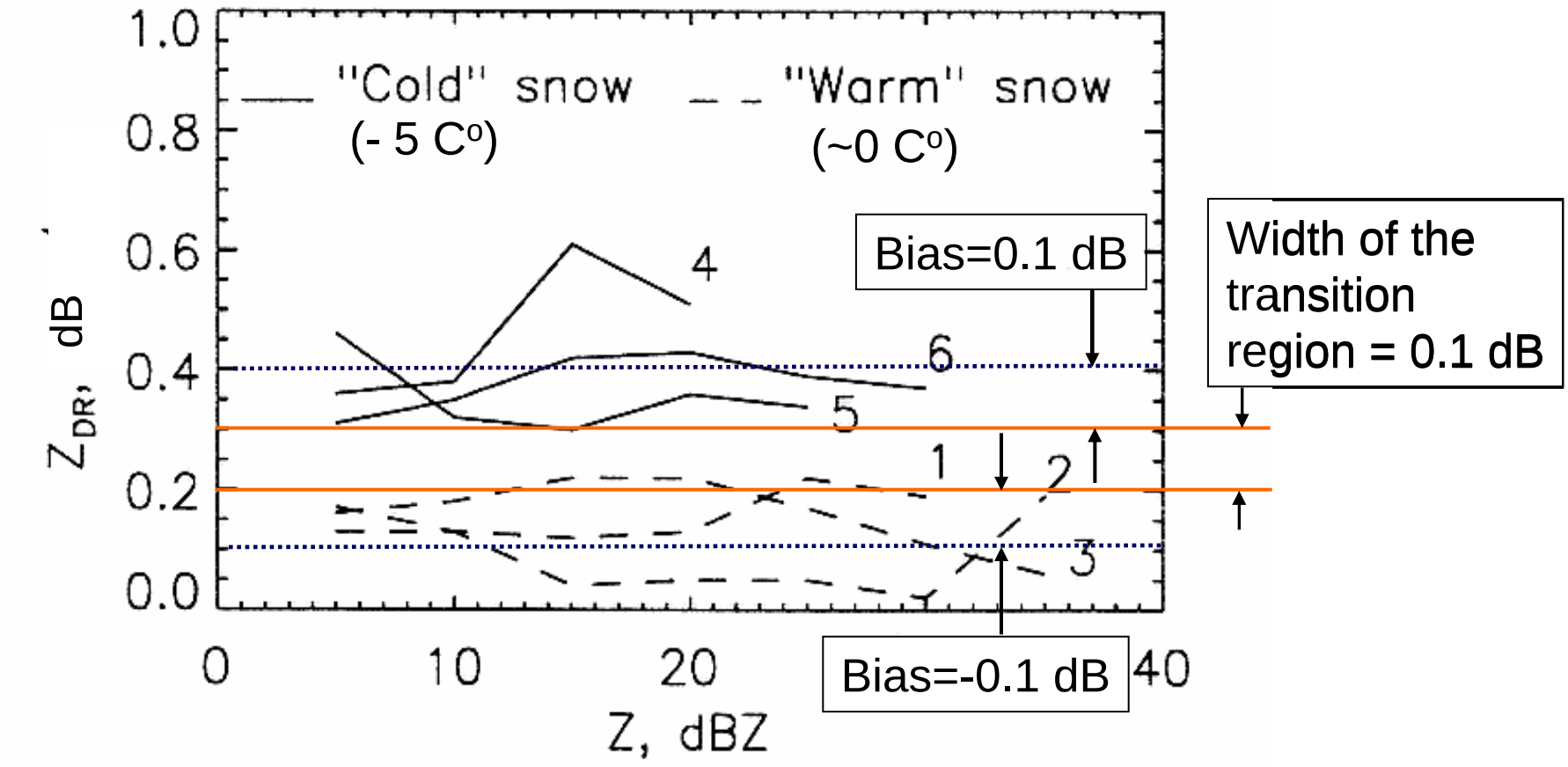


Bias=0.28%

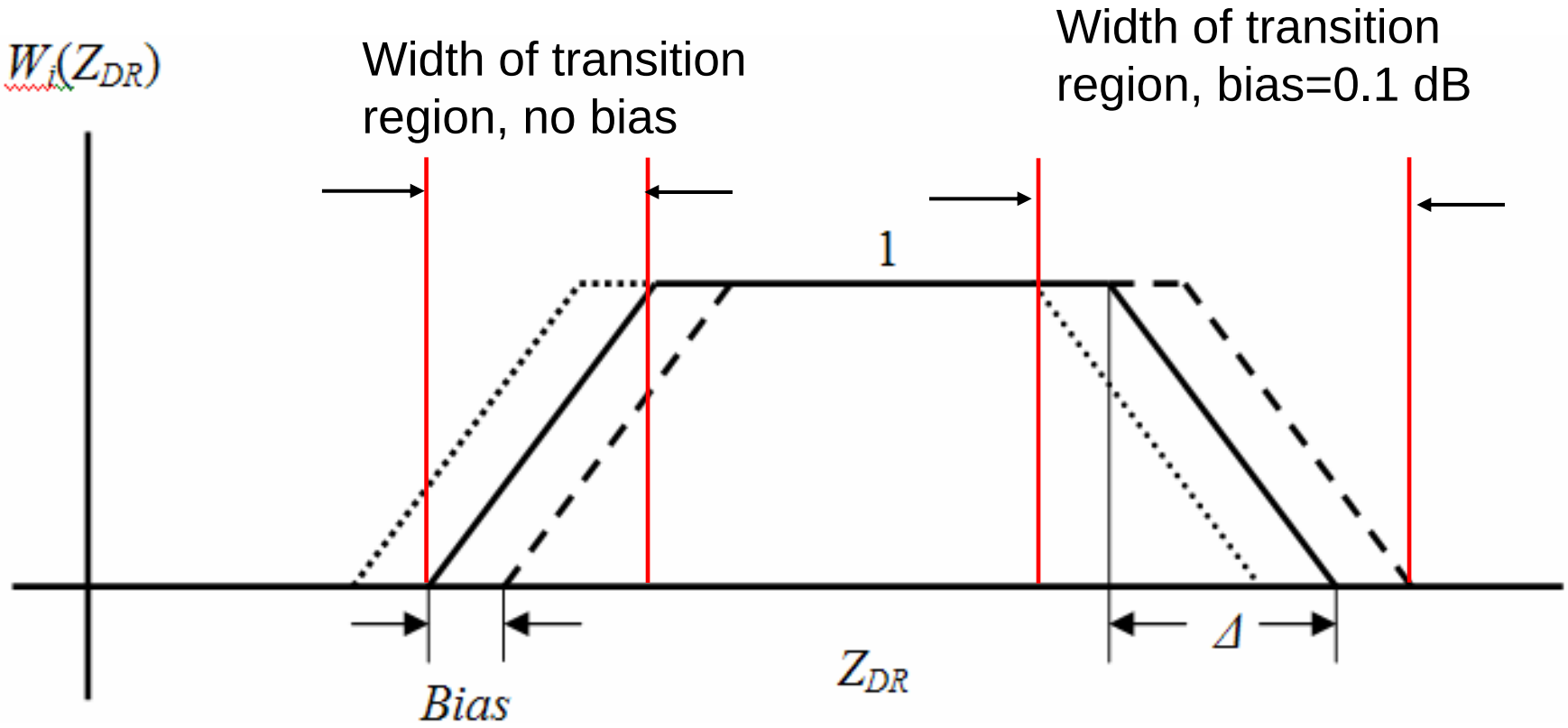
Effects of Bias on Rainfall Measurements

- If the bias in Z_{DR} is 0.2 dB
  - the polarimetric rainfall relation $R(Z, Z_{DR})$ used at moderate rainfall rates (6 to 50 mm h^{-1}) are at least as good (rms errors = 35%) as the R(Z) relation
  - at most values of Z_{DR} the rms errors are smaller
- If the bias in Z_{DR} is 0.1 dB
  - the rms errors in the polarimetric rainfall estimates are smaller than 20%

Effects of Bias on Classification



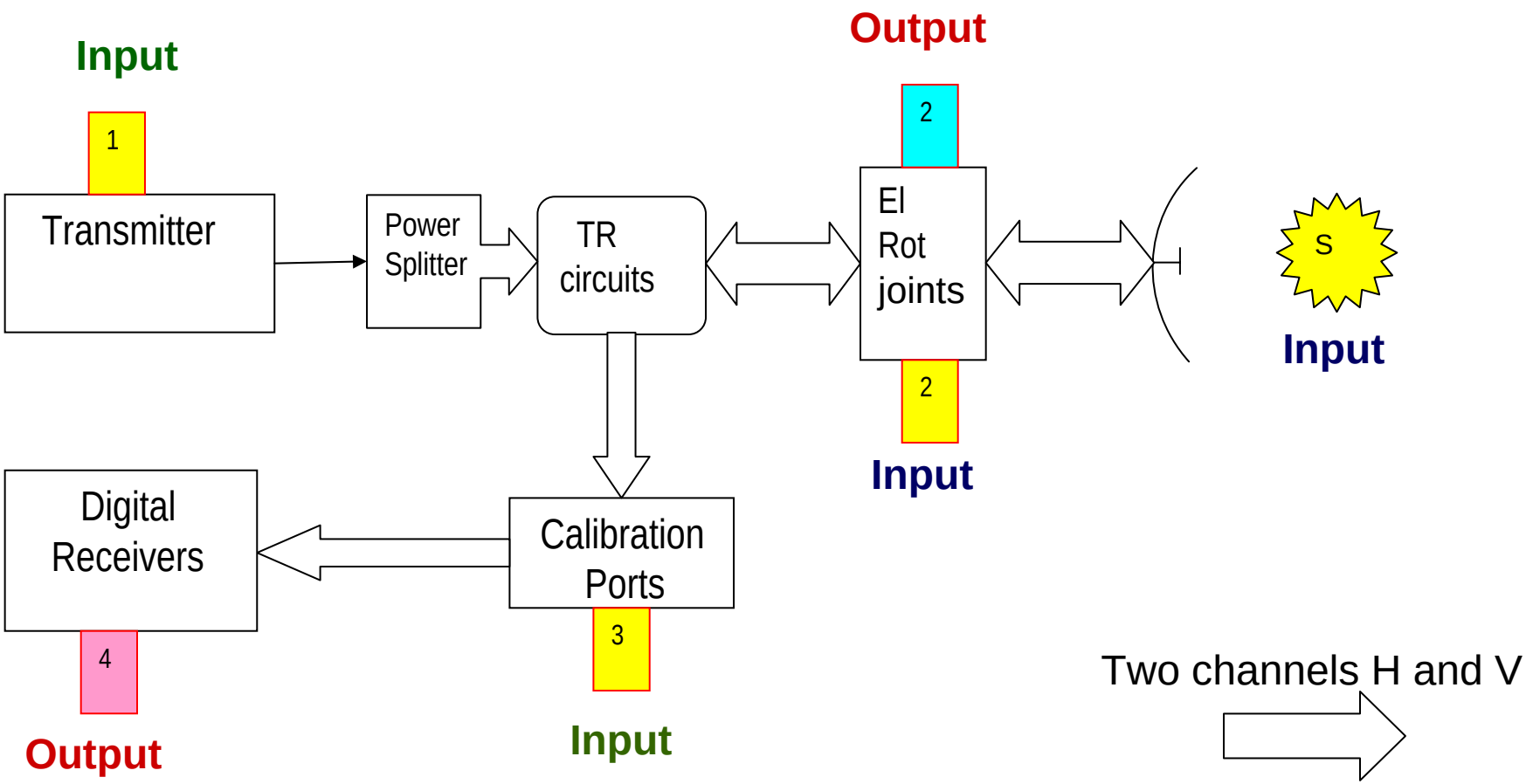
Effects of Bias on Classification



Calibration Needs for the WSR-88D Network

- Calibration at time of retrofit – therefore:
  - Meteorological scatterers – OUT
  - Ground scatterers – POSSIBILITY
  - Sun – POSSIBILITY
  - Instruments - REQUIRED
- Maintain calibration all the time – therefore:
  - Automatic procedure at end of each volume scan - REQUIRED
- Least disturb the system

Calibration Points for Z_{DR} measurements all paths included



Procedure

1) Separate bias in the time invariant part Δ_C and the variable part $\Delta_{34}(P_h)$ so

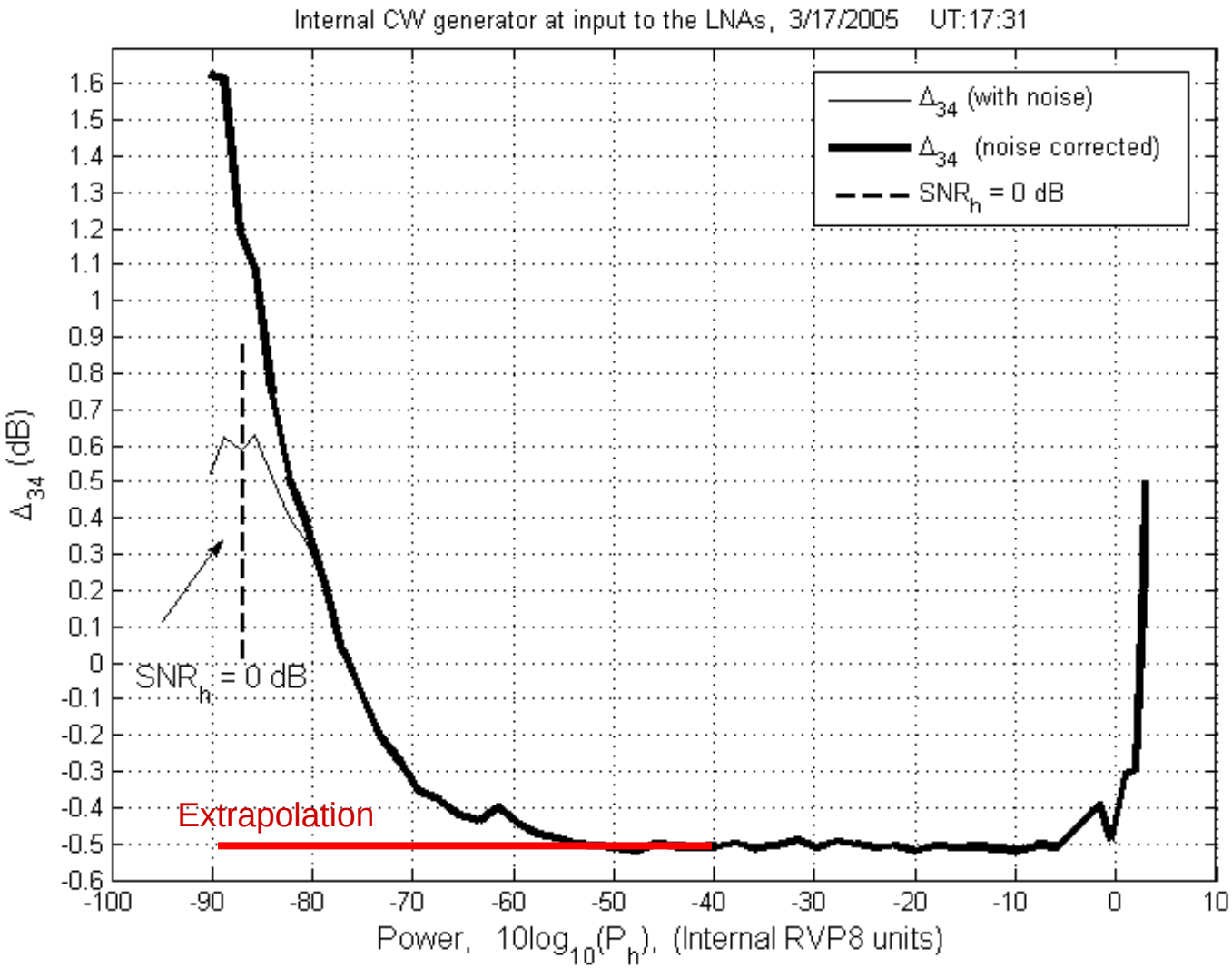
$$\text{Bias} = \Delta_C + \Delta_{34}$$

$$\Delta_C = \Delta_{12} + 2\Delta_{S2} + \Delta_{23}$$

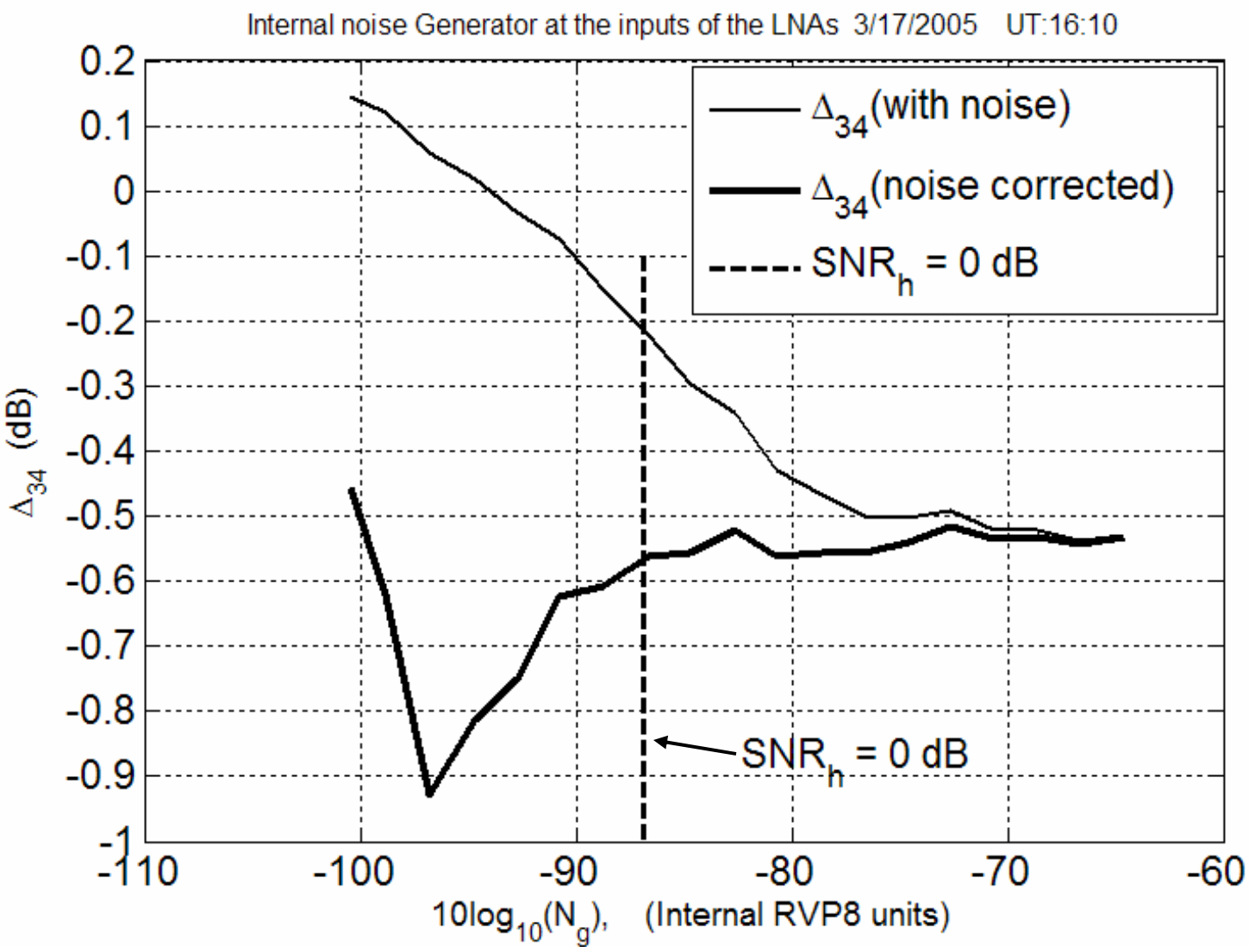
2) Obtain Δ_{12} directly – monitor transmitter power and measure powers at output of El rotary joints

3) To measure bias of the receiver chain use only the output of the digital receiver

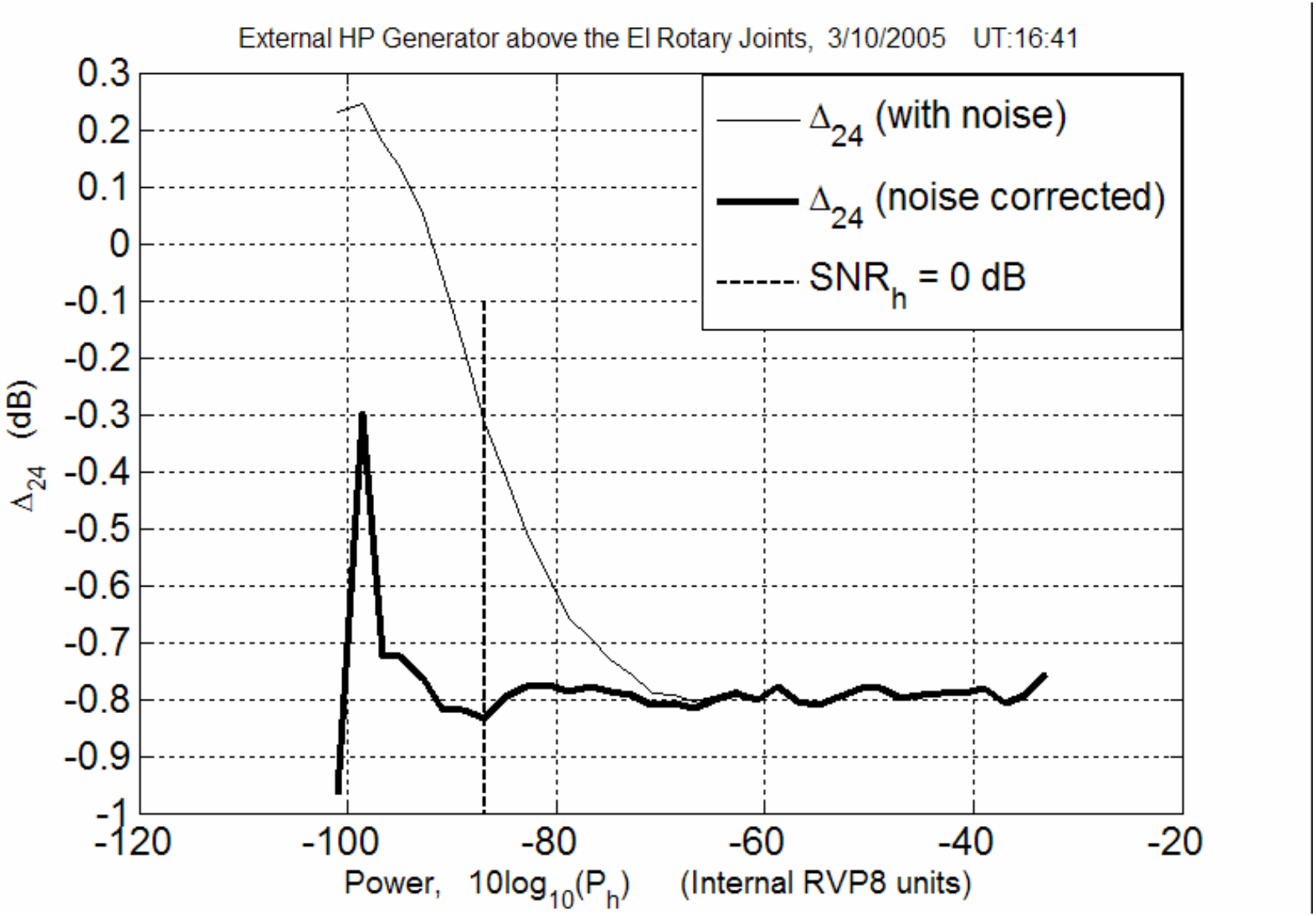
Variable Bias $\Delta_{34}(P_h)$, LNA to Dig Rec – Internal Signal Generator



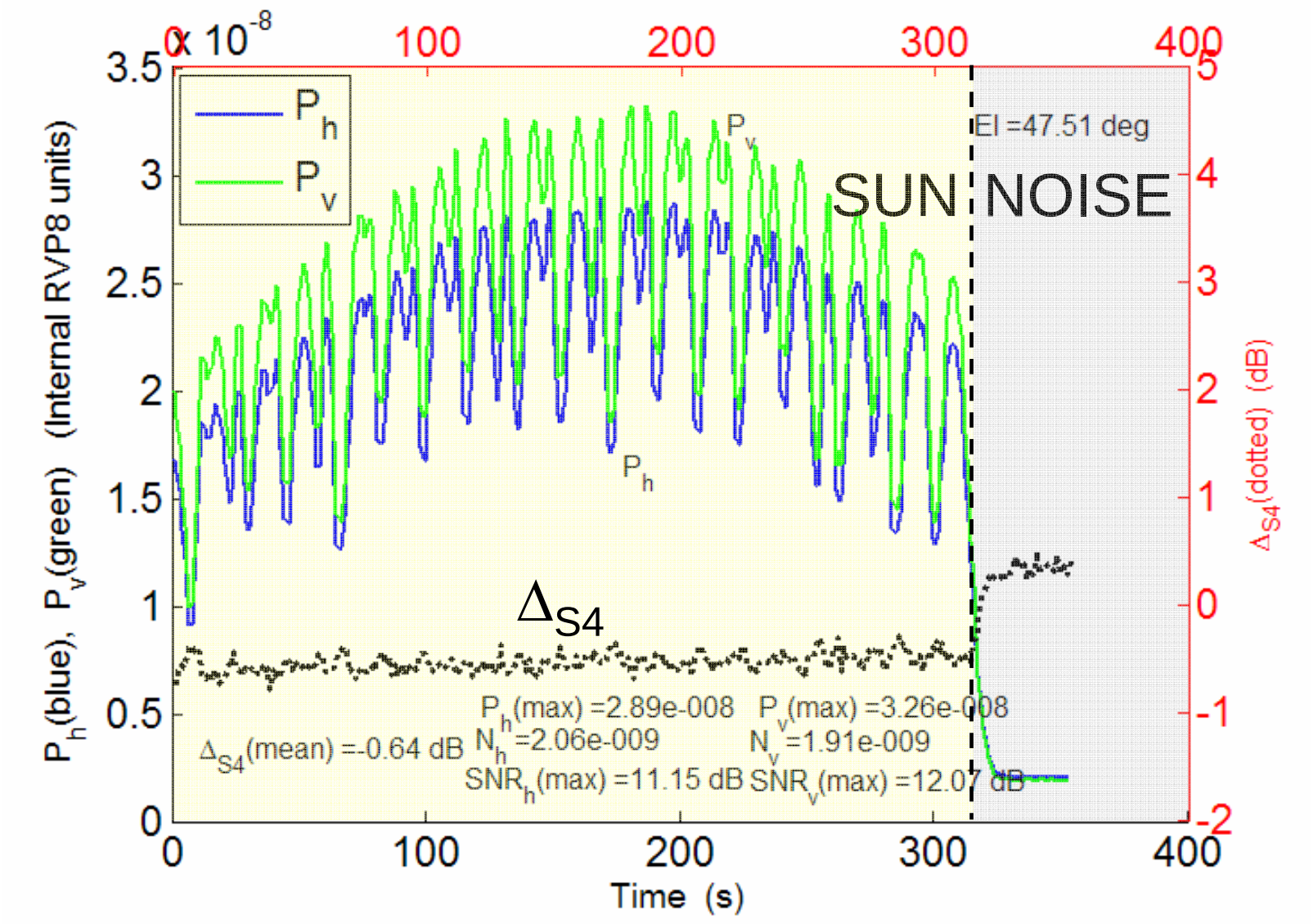
Variable Bias $\Delta_{34}(N_g)$ obtained with the Internal Noise Generator



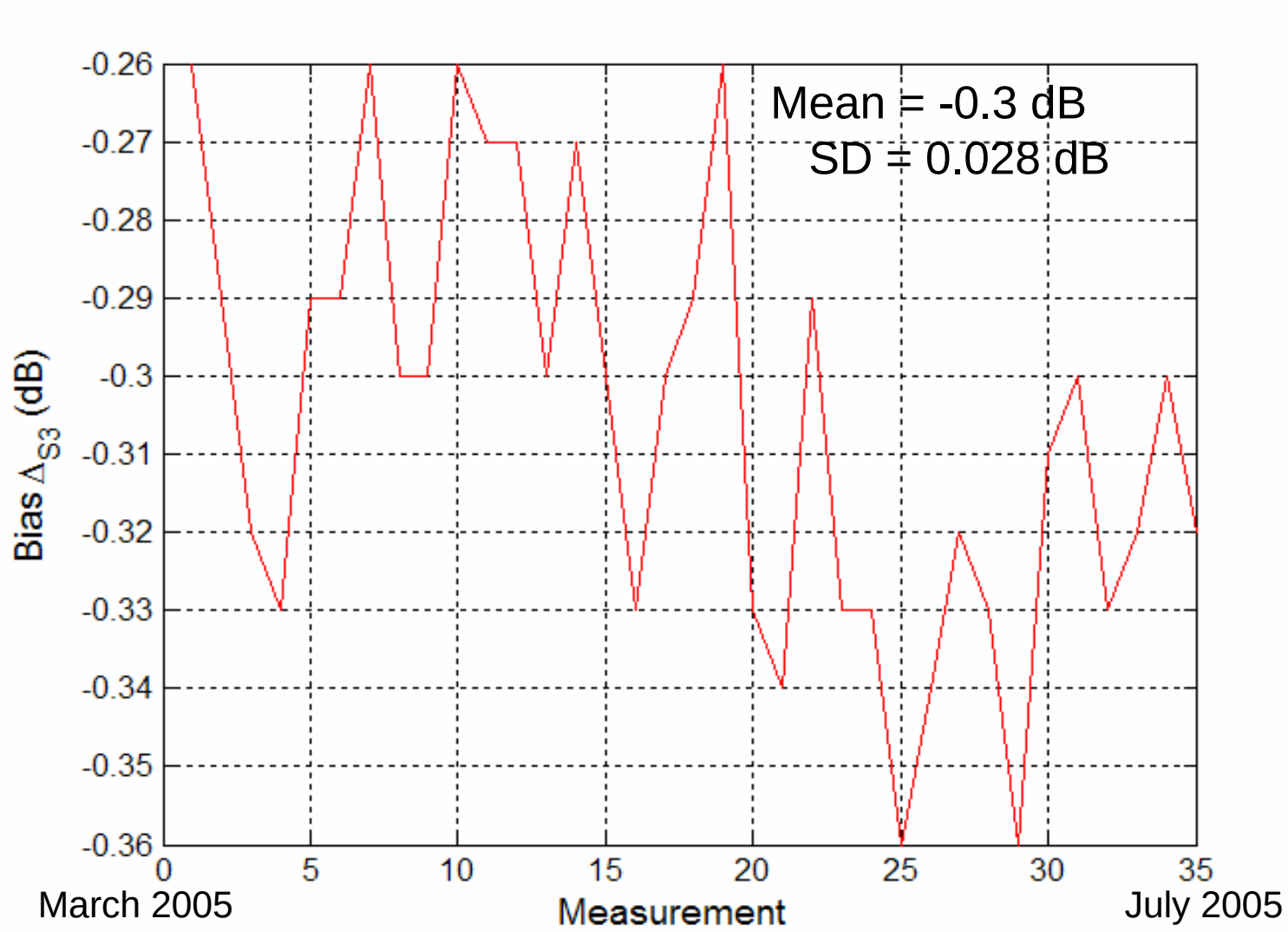
Bias from EL joints to Dig Rec External Generator above EL Joints



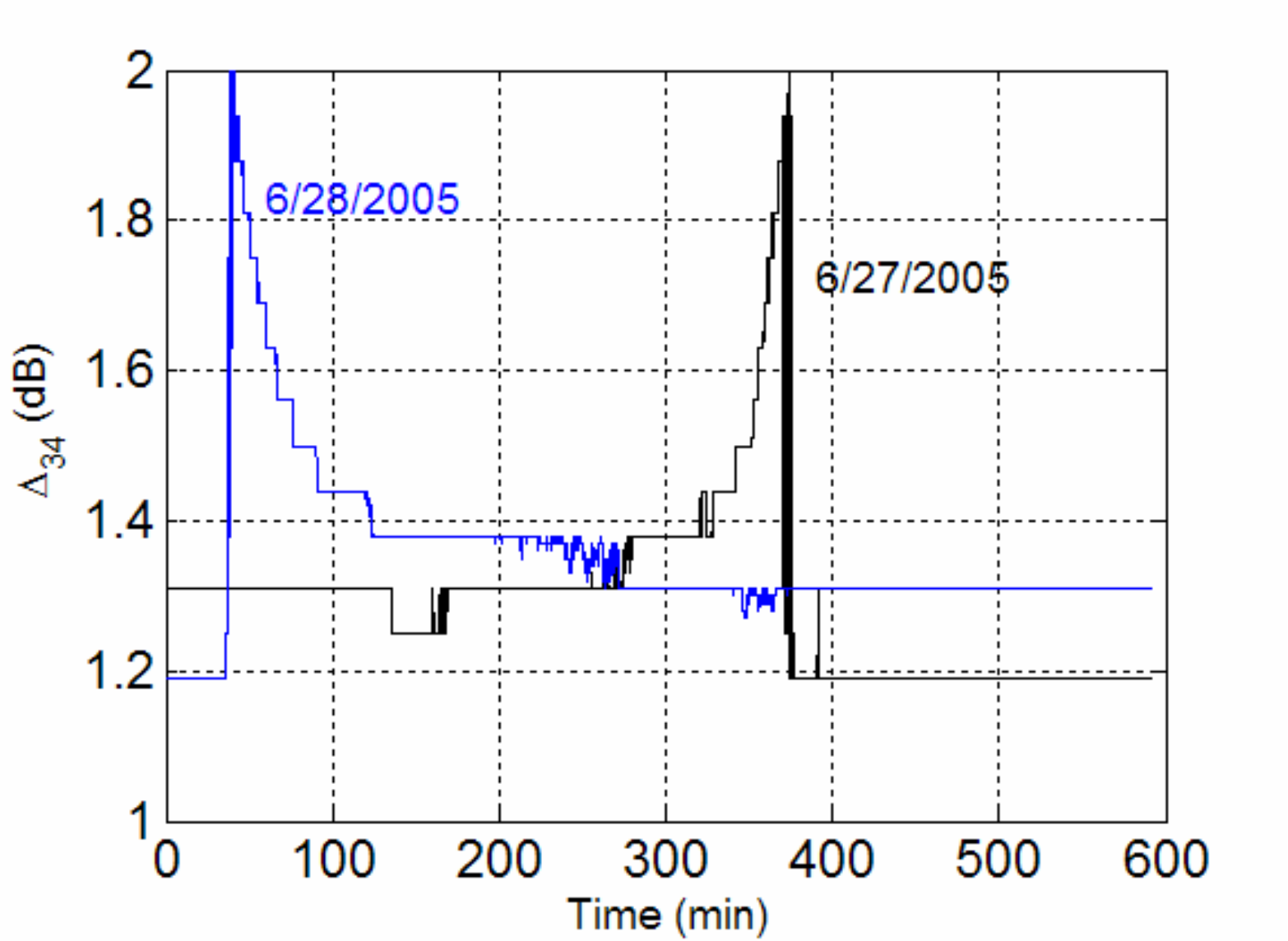
Sun scan: P_h and P_v, and bias component Δ_{S4}



Constant Receiver Bias (Sun to LNA) over a five month period



Bias between LNA and Dig Rec (variations over two 600 min periods)



Error Budget – Estimate

- TR to above El joints,
  - biased: rms(Δ_{12}) <0.04 dB?
- EL joints to out of radome,
  - biased: rms(Δ_{2S}) <0.03 dB?
- Sun to LNA
  - Difficult not biased: rms(Δ_{S3}) <0.03 dB
- LNA to Dig Receiver,
  - Difficult not biased: rms(Δ_{34}) <0.04 dB

Total SD value < 0.1 dB

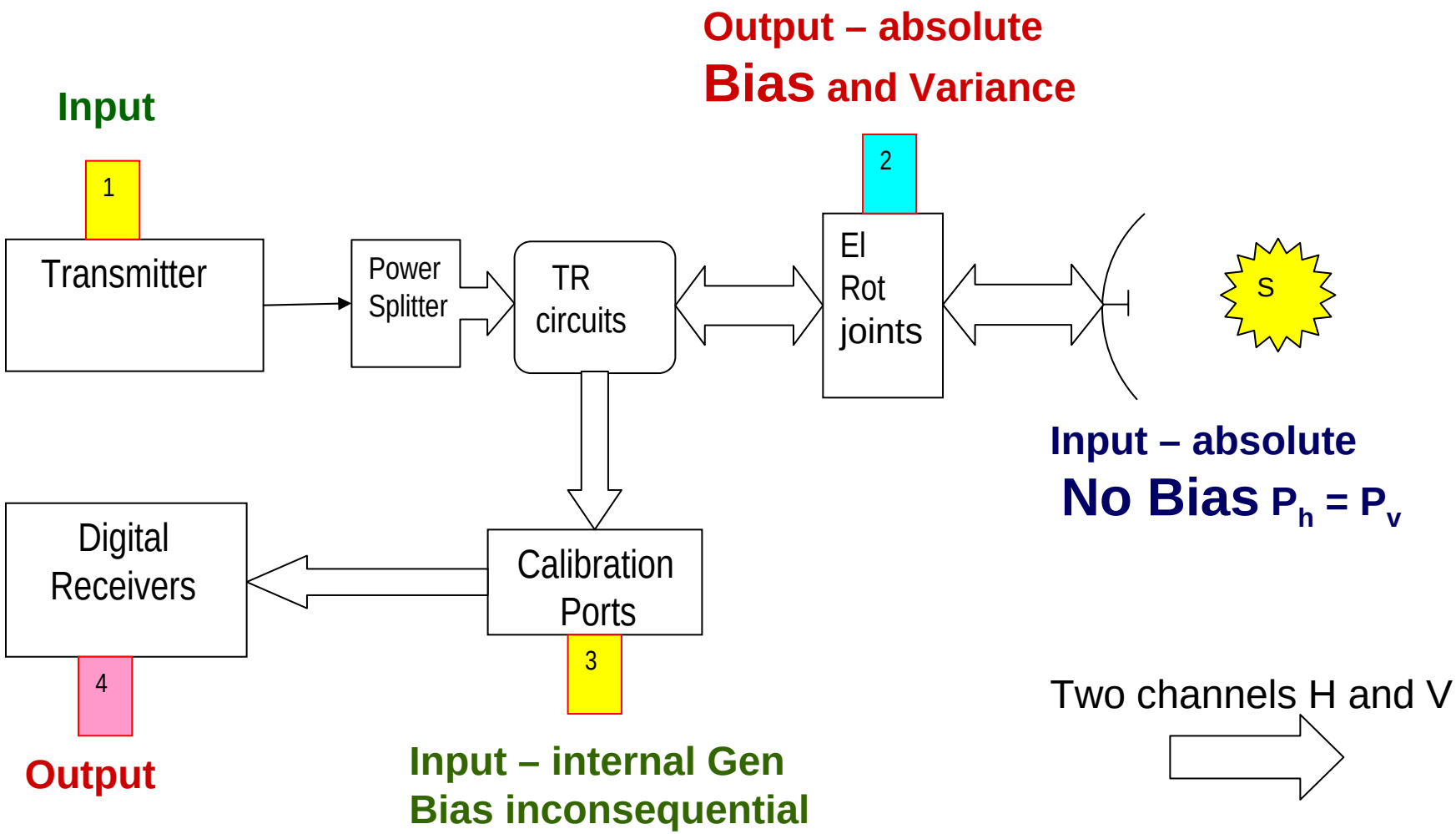
Calibration of ZDR on the WSR-88D Version I: PROCEDURE

- The procedure uses existing components on the WSR-88D and the Sun
- The bias consists of a constant part and a time varying part
- The constant bias is obtained from three sets of measurements (one in the transmission chain two in the receiver)
- The time varying part must be measured automatically at the end of each volume scan
- Measurement over any part of the active receiver path must be preceded and followed by automated rapid measurement of the active part

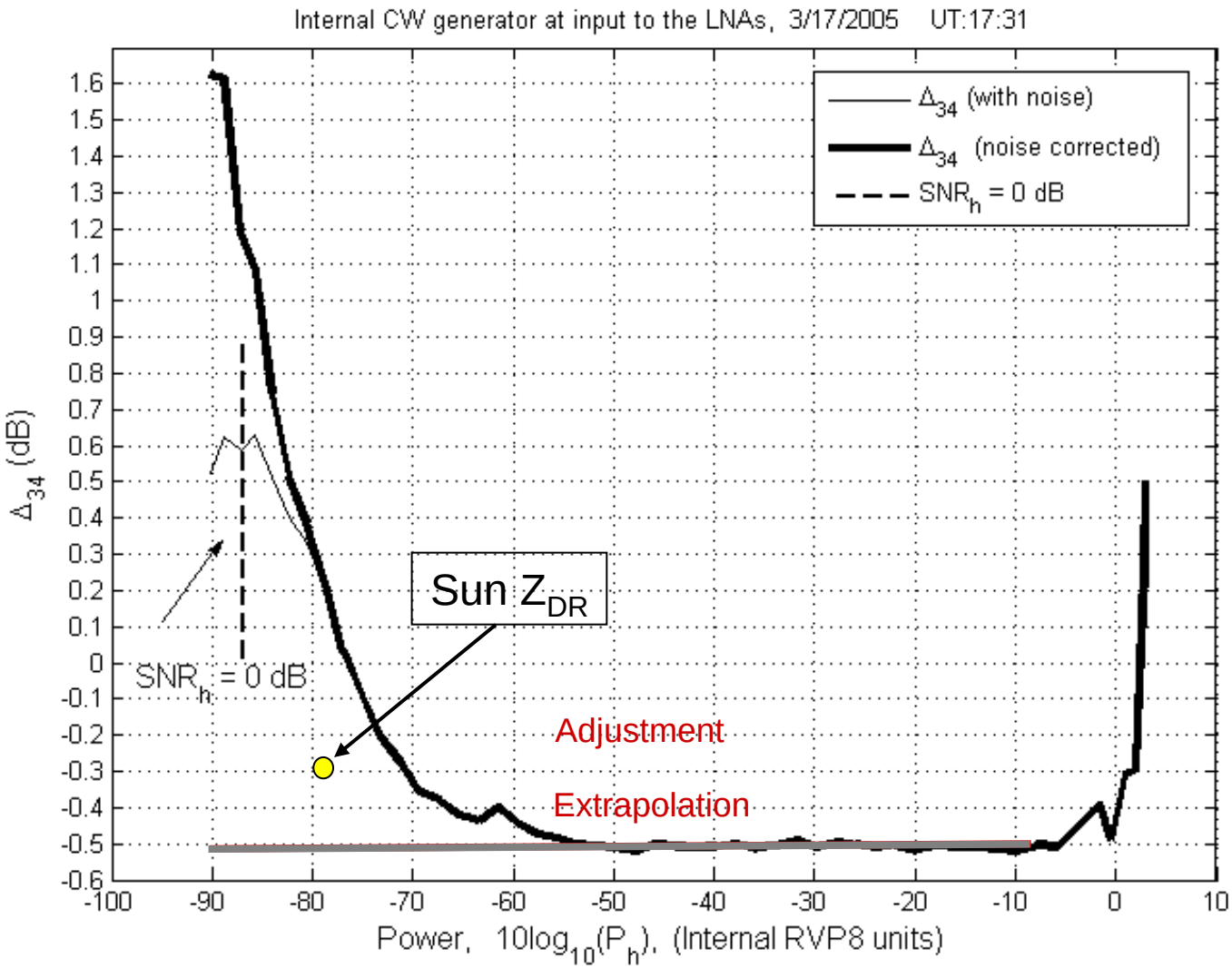
Calibration of Z_{DR} on the WSR-88D Version I: FINDINGS

- The Z_{DR} BIAS is constant over the dynamic range of the receiver
- Coherent leakage caused by the internal frequency generator
  - SOLUTIONS:
    - EXTRAPOLATE THE VALUES FROM HIGH POWERS TO LOW POWERS
    - VERIFY WITH INTERNAL NOISE GENERATOR
- Abrupt discontinuities in bias caused by differential temperature in the LNA enclosures
  - SOLUTIONS:
    - AUTOMATIC CALIBRATION AT END OF VCP
    - FORCE TEMPERATURE CONTROL IN THE TWO ENCLOSURES TO BE THE SAME
- The SUN is an excellent source for calibration
  - IT HAS ZERO BIAS
  - SD OF ERROR CAN BE MADE MUCH SMALLER THAN 0.1 dB
- Achievable rms error should be ~ 0.1 dB

VERSION II: Calibration of Z_{DR} excluding path 2 (EL joints) to SUN



Variable Bias $\Delta_{34}(P_h)$, LNA to Dig Rec – Adjustment using Sun scan



Repeated Measurements – Transmission Path above El Joints

- Two power meters, 15 measurements:
  - Mean = -0.057 dB, SD = 0.006 dB
- One power meter, connected and disconnected 10 times
  - Mean = -0.088 dB, SD = 0.004 dB

- Previous measurement: Mean ~ -0.06 dB

Error Budget – Estimate

- TR to above EL joints,
  - biased: rms(Δ_{12}) <0.03 dB?
- EL joints to out of radome,
  - ignore: rms(Δ_{2S}) <0.06 dB?
- Sun to Dig Receiver
  - Easy not biased: rms(Δ_{S3}) <0.03 dB

Total rms value < 0.08 dB

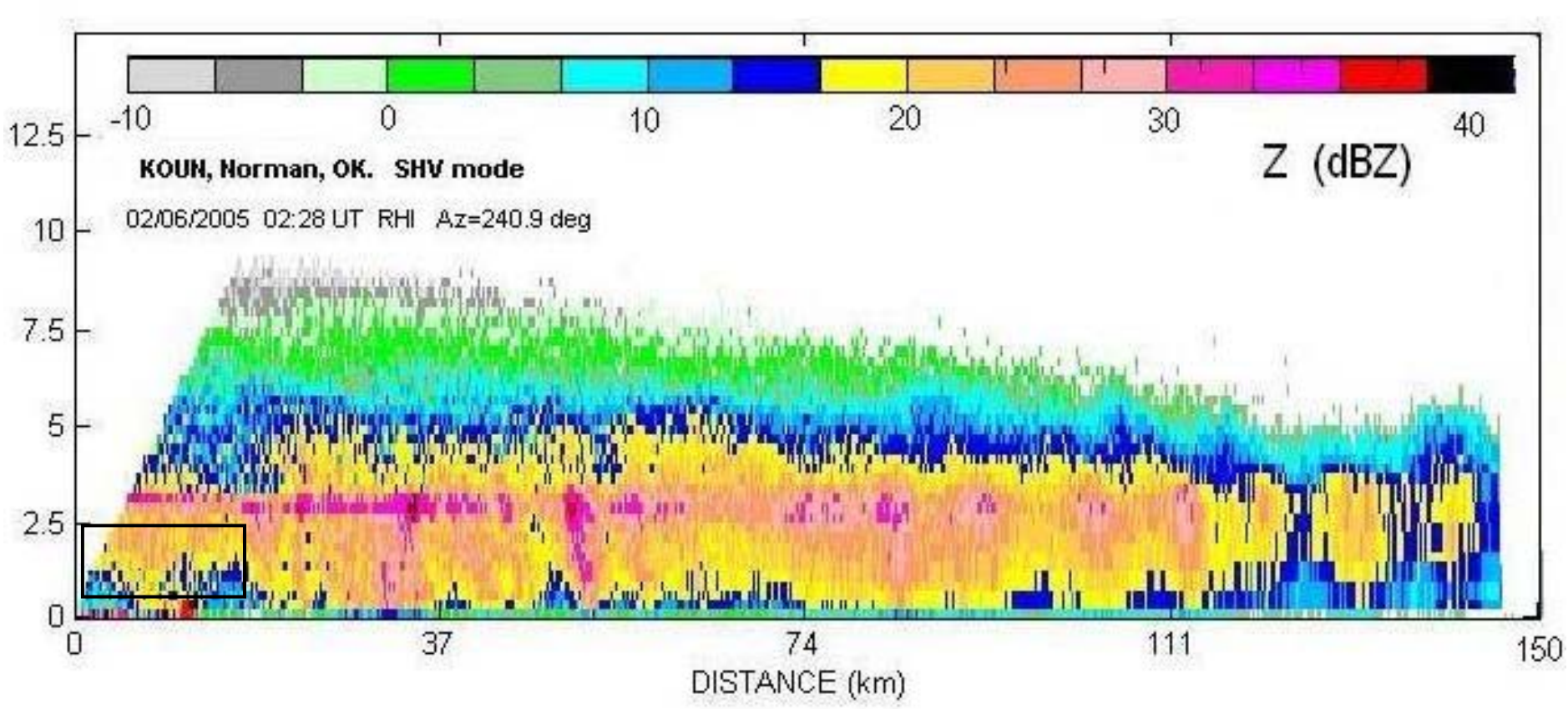
Calibration of ZDR on the WSR-88D Version II: PROCEDURE

- The procedure uses existing components on the WSR-88D and the Sun
- The bias consists of a constant part and a time varying part
- The constant bias is obtained from two sets of measurements - one set has no BIAS
- The time varying part must be measured automatically at the end of each volume scan
- Much easier to make in the field

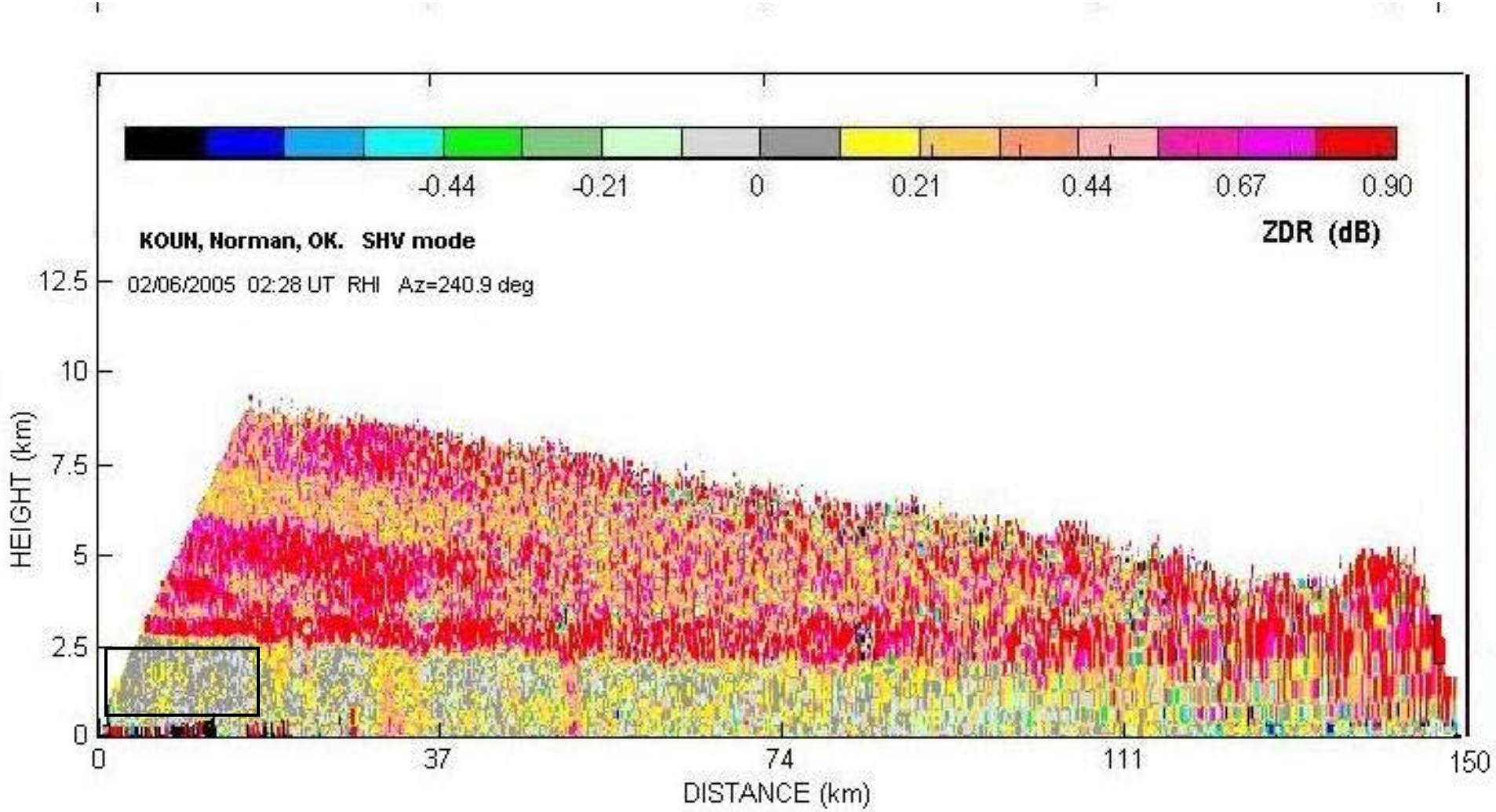
Calibration of ZDR on the WSR-88D Version II: FINDINGS AND ISSUES

- Sun - equality of the H and V polarizations
  - NCAR's redundant measurements during quiet (no sun spots) period indicate excellent match
- Sun – standard deviation of measurements
  - NSSL's result ~ 0.028 dB
  - NCAR's result ~ 0.024 dB
- Measurement in the transmitter chain
  - Bias at couplers above El rotary joints
  - Value of ignored bias from the EL joints to outside of radome

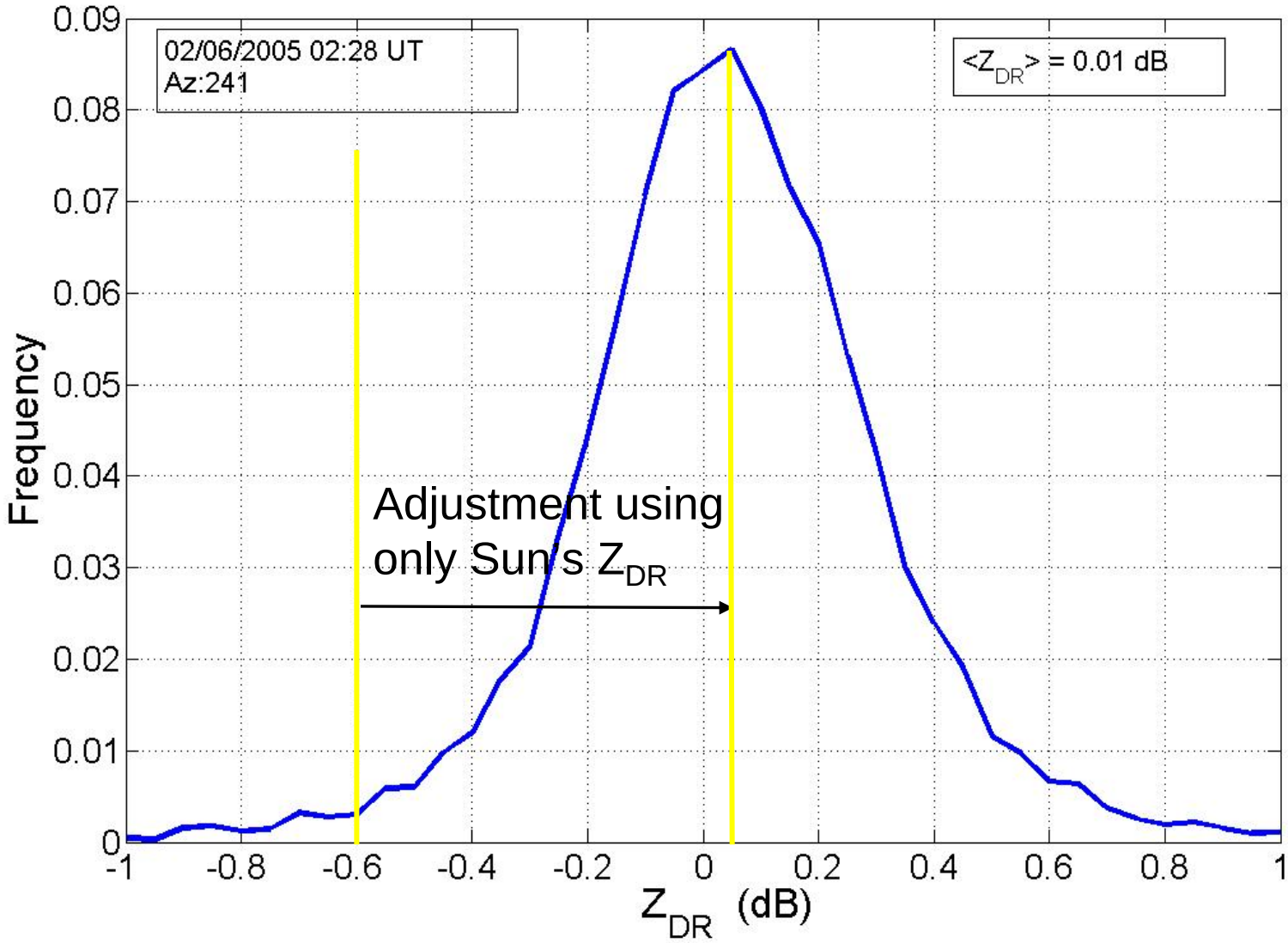
Measurement in Drizzle: Z Field



Measurement in Drizzle: Z_{DR} Field



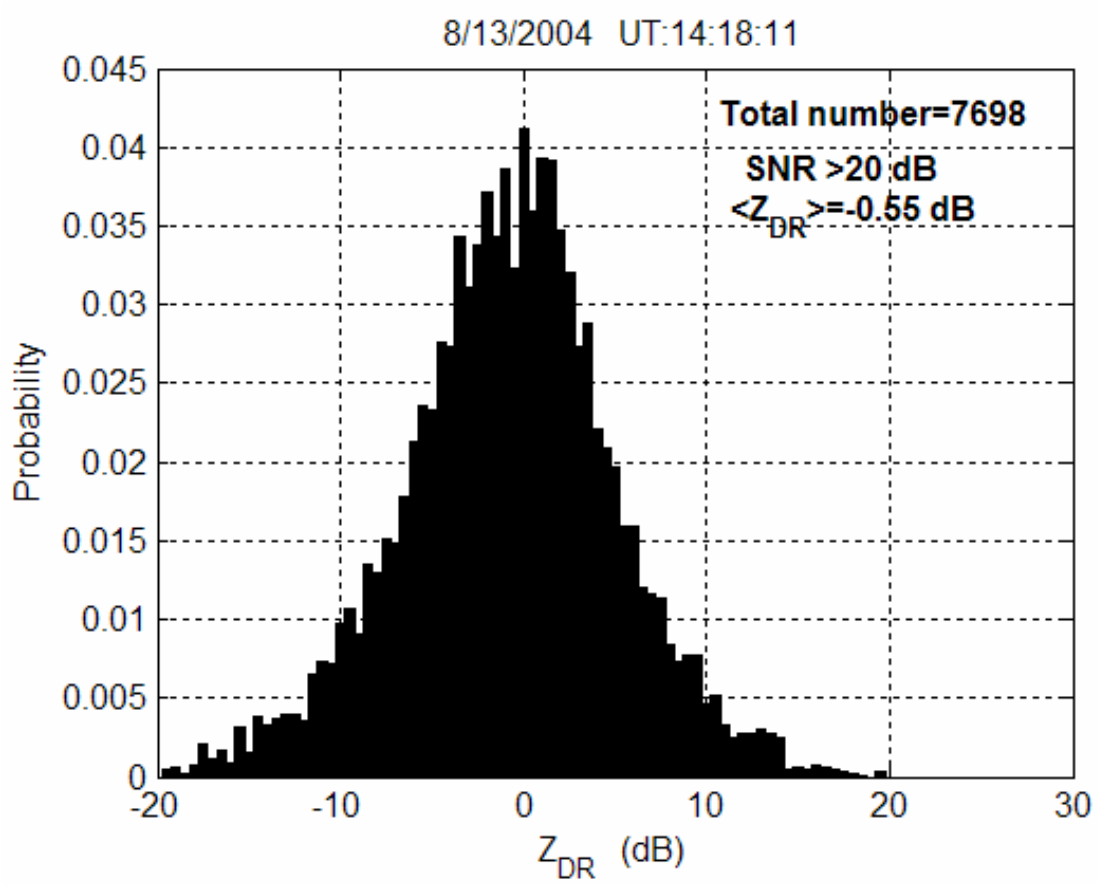
Histogram of Z_{DR} in Drizzle

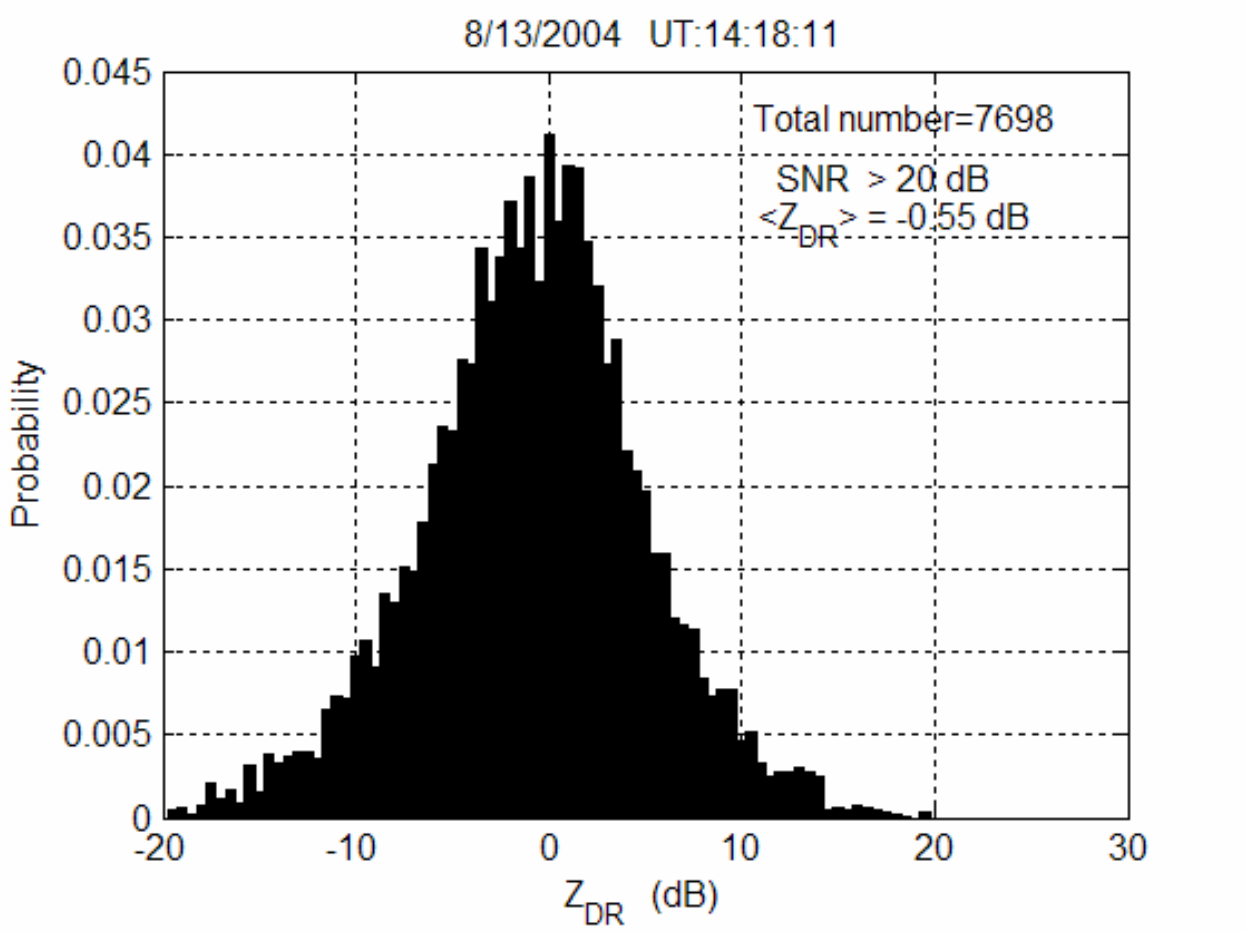


Path to Resolution

- NSSL measurement on the RRDA
  - Automatic part of calibration has been implemented, it enables perfect relative tracking of the bias
  - Compare results from the procedure with measurements in precipitation at 60 deg elevation
- NWS to check the precision and bias of the couplers?
- NCAR measurements ?

END


8/13/2004 UT:14:18:11
Total number=7698
SNR >20 dB
<Z_DR>=-0.55 dB
Probability
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-20
-10
0
10
20
30
Z_DR (dB)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<Z_DR> = -0.55 dB
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0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-20
-10
0
10
20
30
Z_DR (dB)

Procedure - continuation

4) Precede and follow the measurement at the output of the digital receiver with the measurement from the calibration port
   - For example obtain Δ_{23} as $\Delta_{23} = \Delta_{24} - \Delta_{34}$, by measuring first Δ_{34} then Δ_{24} and again Δ'_{34}
   - Accept the measurement if Δ_{34} and Δ'_{34} are within 0.03 dB!

5) Sun scan followed immediately by noise power measurements in each channel N_h and N_v - subtract these from the total powers P_h and P_v

6) Internal noise generator and sun scan to measure $\Delta_{S4} - \Delta_{34}$

7) Internal signal generator and external generator to obtain $\Delta_{24} - \Delta_{34}$

8) Compute

$$\Delta_{S2} = \Delta_{S4} - \Delta_{34} - (\Delta_{24} - \Delta_{34})$$