



NWSTC WSR-88D Webinar Series

Receiver/Signal Processor Calibration

Off-Line measurement and update of adaptation data used by the system during automatic on-line and off-line calibrations

This presentation is not a replacement for attendance at the In-House WSR-88D training

The objective is to clarify the field technician's understanding of the what and why of the calibration, not so much the how-to of the procedure (see NEXRAD Job Aids for that).

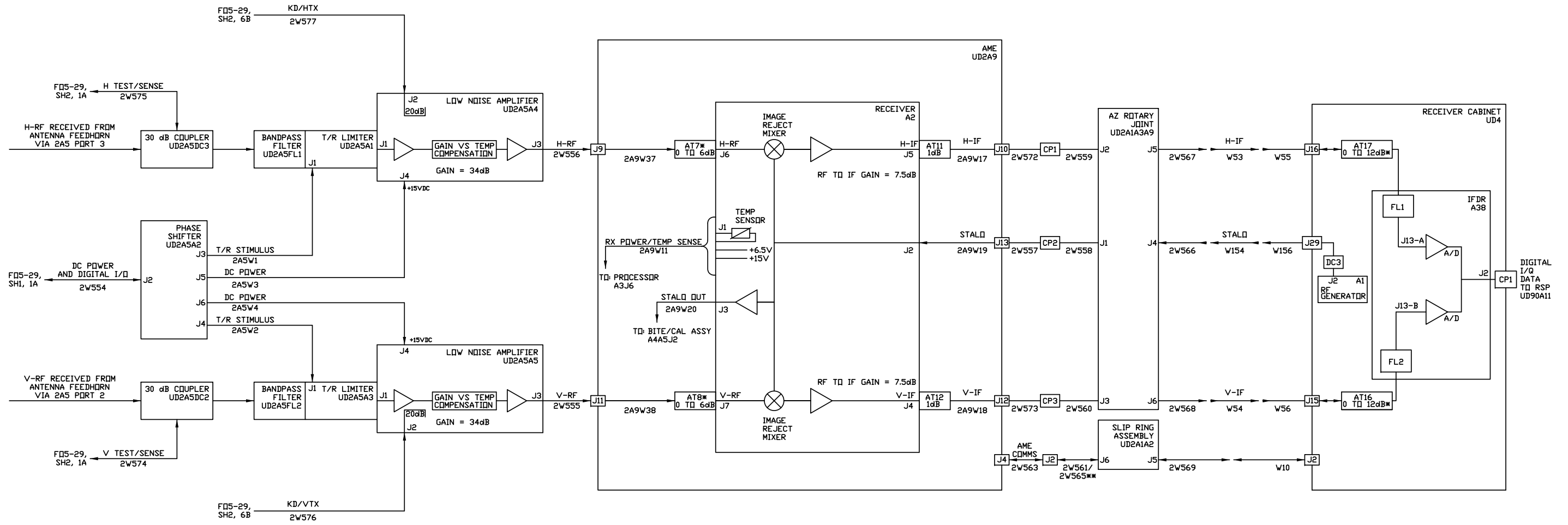
[Link to NWSTC website](#)

References

- EHB 6-513 R2, 25 Jun 2020
- EHB 6-513-1 R2 25 Jun 2020
- NWSTC Receiver Calibration Notes, 11 Jan 2021
- NWSTC WSR-88D Test Paths Drawing, 08 Nov 2016

SINGLE CHANNEL SYSTEMS

NOTES:
* SITE SELECTED
** LPP



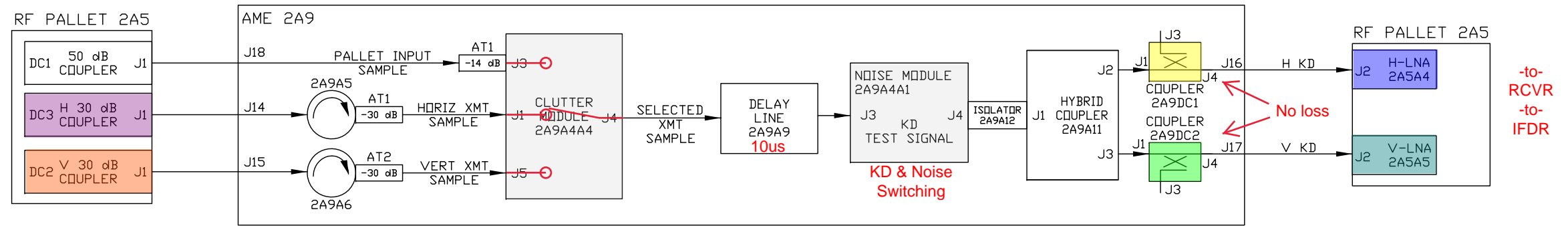
NX3853-E

Figure 5-1. Receiver Signal Flow Block Diagram (Sheet 1 of 3)

(From Table 5-2)

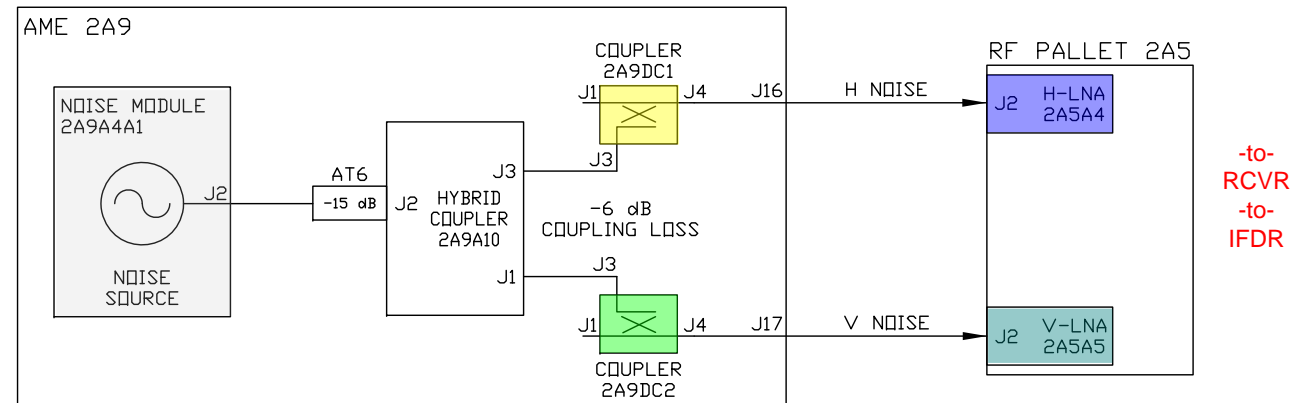
- Clutter Suppression
- RF Gen Phase Shifter Chk
- Power Sense

KD PATH
(5.4.6.1)



- Sys Noise Temp
- Sun Check

NOISE PATH
(5.4.6.2)



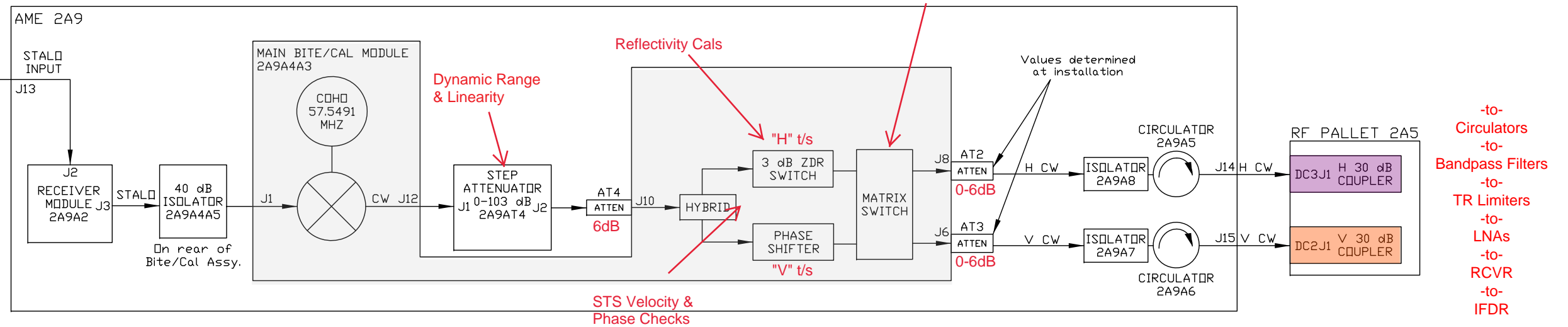
Test Paths

(Table 5-3)

- Switch Options:
- Straight
 - Swapped
 - H to V (H isolated)
 - V to H (V isolated)
 - H only (V isolated)
 - V only (H isolated)
 - H to Both
 - V to Both
 - Isolated

- Linearity
- RCVR Bias

CW PATH
(5.4.6.3)



NX3975-C

Figure 5-5. Test Signal Path Block Diagram

On-Line Calibration

- The RDA software is initially loaded with horizontal and vertical system calibration values for reflectivity(H & V dBZØ) .

The calculation of dBZØ includes:

- Transmitter power
- Receiver path gain
- Noise (external interference, IFDR, shared path)
- IØ (AME Test Signal, low noise amplifier, receiver, step attenuator)
- Adaptation Data

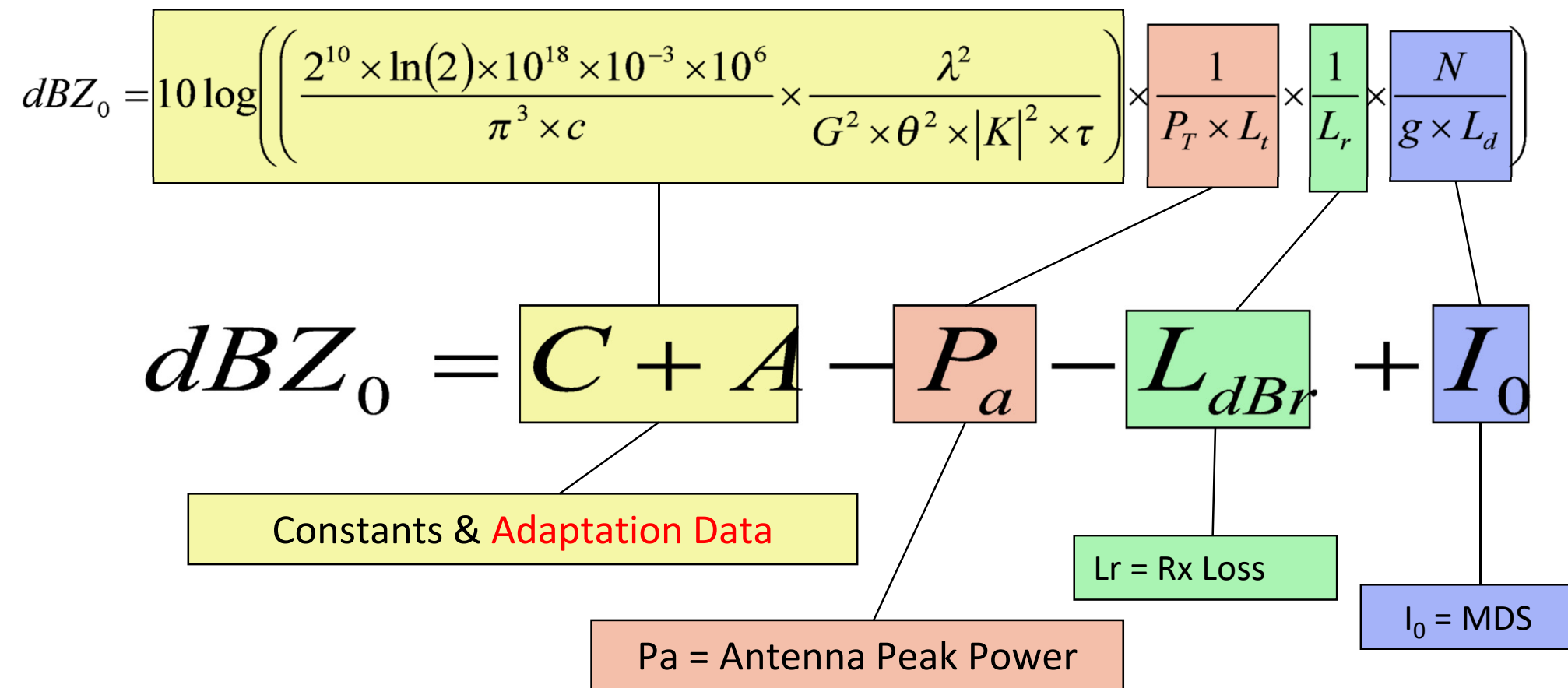
dBZ₀ (Reflectivity Calibration Constant)

Represents the reflectivity of a 0dB Signal-to-Noise target at a range of 1km, including all constants in the radar.

- Compensates for system variables (Transmitted Power, Receiver Losses and system MDS)
- The horizontal and vertical channels have individual dBZ₀ values that are determined by Linearity Check.

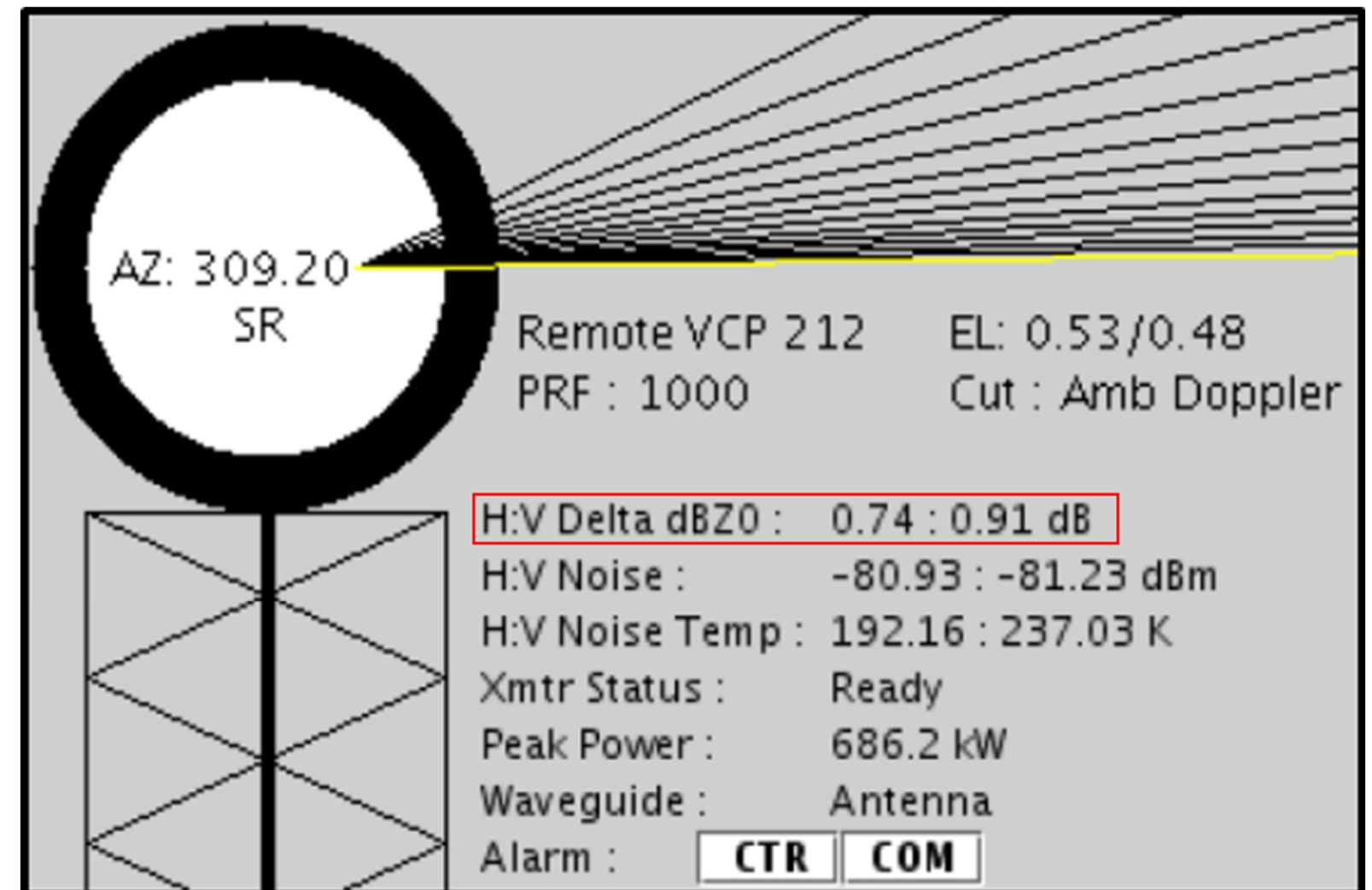
dBZ₀ (Reflectivity Calibration Constant)

$$dBZ_0 = 10 \log \left(\frac{2^{10} \times \ln(2) \times \lambda^2 \times 10^{18} \times 10^{-3} \times 10^6}{\pi^3 \times P_T \times G^2 \times \theta^2 \times c \times \tau \times |K|^2 \times L_t \times L_r \times L_d} \times \frac{N}{g} \right)$$



On-Line Calibration

- During the on-line calibration performed at every volume scan, the horizontal and vertical dBZØ values, calculated from test signal measurements, are compared to the original calibration values and the difference is displayed on the RDA HCI as H:V Delta dBZØ.



Off-Line Calibration

- The accuracy of our adaptation data directly affects dBZ \emptyset , therefore the accuracy of all reflectivity products, differential reflectivity, and the I \emptyset of the RDA.
- Adaptation data determined during the Off-Line Receiver Calibration is used by On-Line Calibration routines to detect changes in test signal strength and set alarms.

When to Calibrate?

- When certain LRUs in the receiver path or AME have been replaced (see EHB 6-513 Table 6-15).
- When directed to by following a troubleshooting flow chart
- When called for by other procedures ie: Suncheck
- If the H or V Delta dBZØ is greater than 0 ± 1.5 dB, the cause must be identified and corrected before calibrating, if possible.

When to Calibrate?

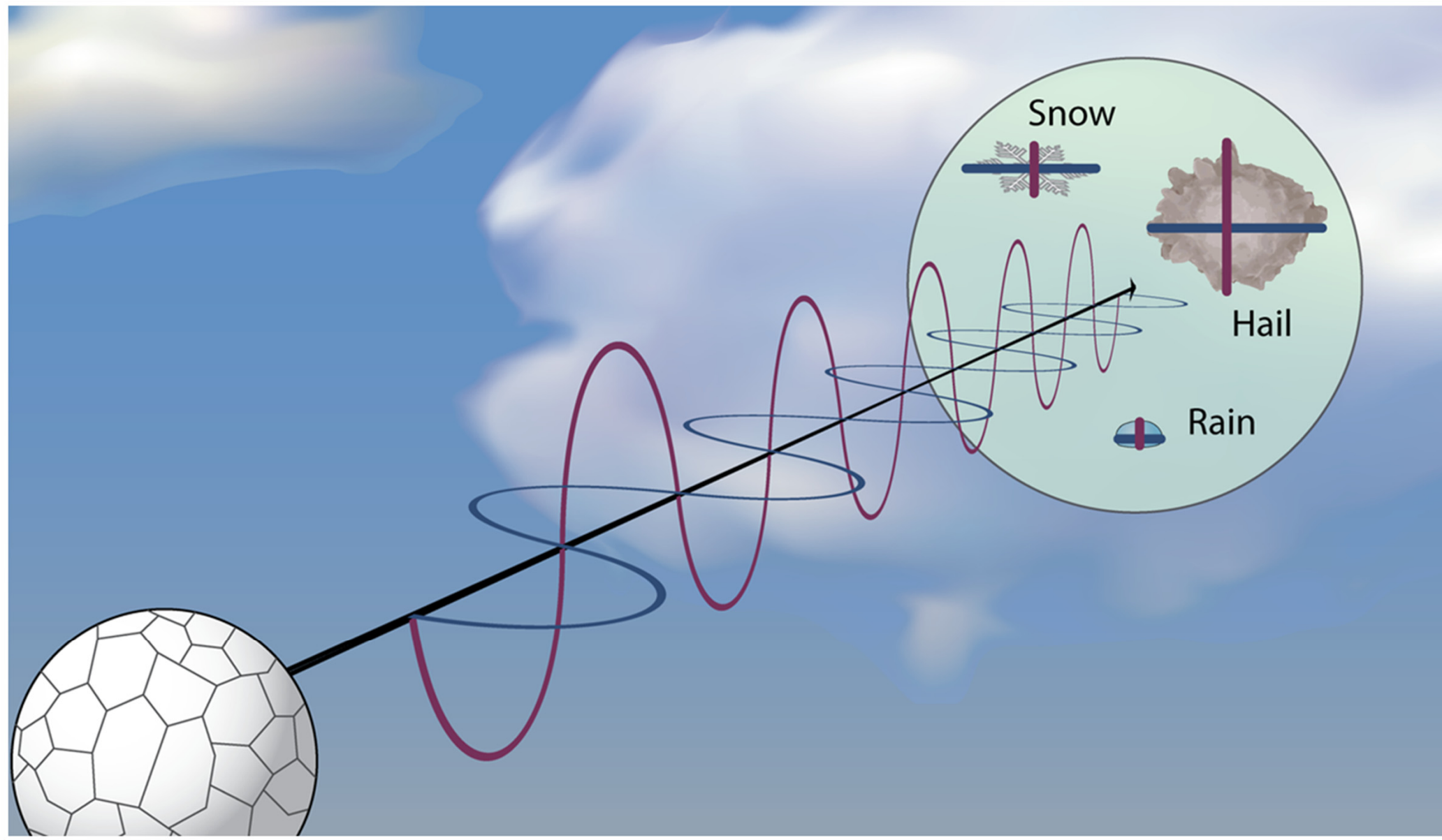
- It is necessary to perform an Off-Line calibration when alarms that monitor the test signals used for the reflectivity calibration and check are detected.
- These alarms are:
 - HORIZONTAL POWER SENSE LOW (477)
 - VERTICAL POWER SENSE LOW (478)
 - SYSTEM DIFFERENTIAL REFLECTIVITY BIAS DEGRADED (479)
 - HORIZONTAL GAIN CALIBRATION CONSTANT DEGRADED (481)
 - VERTICAL GAIN CALIBRATION CONSTANT DEGRADED (480)
 - HORIZONTAL LINEARITY TEST SIGNAL DEGRADED (523)
 - VERTICAL LINEARITY TEST SIGNAL DEGRADED (525)
 - KLYSTRON OUT TEST SIGNAL DEGRADED (533)

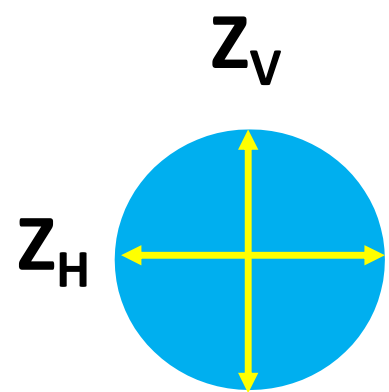
What is ZDR?

- Z = Reflectivity
- ZDR = Differential Reflectivity
 - ZDR is the log of the ratio of the horizontal to vertical power returns in a pulse volume

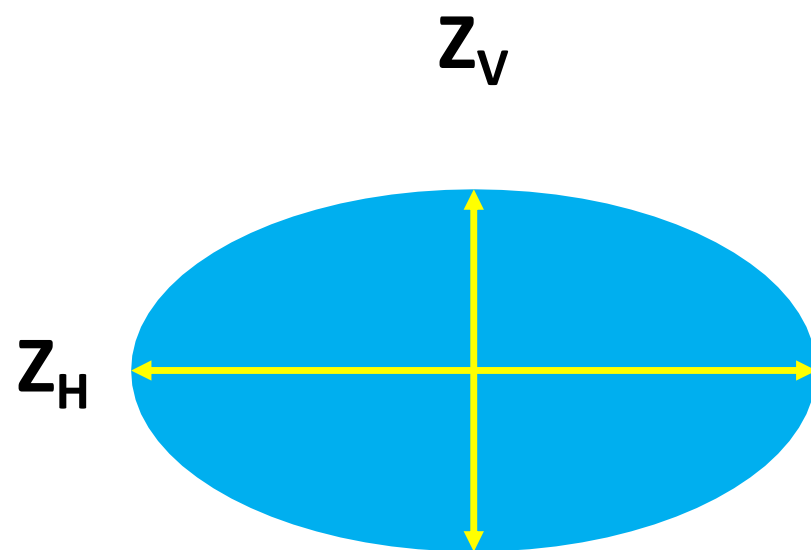
$$ZDR = 10\log_{10}\left(\frac{Z_h}{Z_v}\right)$$

What is ZDR?

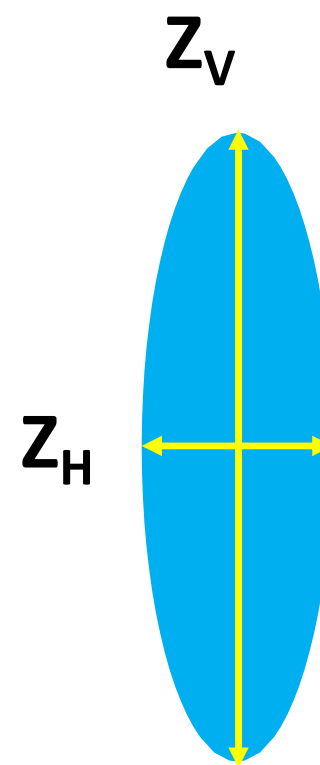




ZDR = 0 dB



ZDR = >0 dB



ZDR = <0 dB

ZDR Offset

- $\text{ZDR Offset} = (2 * \text{SMB}) + \text{RCB} + \text{TXB}$
- All three ZDR Offset parameters (SMB, RCB, and TXB) rely upon IFDR measurements.
 - IFDR used as the measuring instrument since it is more accurate, stable, and repeatable than a power meter.
- SMB affects transmit and receive (suncheck can be an issue here)
- For more information see EHB 6-513 (5.5.3.6.12)

ZDR Adaptation Data

Eleven Adaptation Data values critical to ZDR Offset: R293, R294, R295, R296, R297, R298, A023, A014, A015, A031, and R275.

R293, R294, R295, R296 = RF pallet H and V 30 dB Coupler Factory Measurements from the RF Pallet Factory Test Data Sheet

- R293, R294: Critical for RCB on-line calibrations and SMB off-line calibration
 - R293 = RF Pallet Horizontal Coupler Test Signal Loss
 - R294 = RF Pallet Vertical Coupler Test Signal Loss
- R295, R296: Critical for TXB on-line calibration
 - R295 = RF Pallet Horizontal Coupler Transmitter Loss
 - R296 = RF Pallet Vertical Coupler Transmitter Loss

ZDR Adaptation Data

- R297, R298 = Crossed and Straight Calibration Measurements
 - R297: Critical for RCB on-line calibrations and SMB off-line calibration
 - R297 = AME Test Signal Bias
 - R298: Critical for TXB on-line calibration
 - R298 = Power Sense Calibration Offset Bias
- A023 = Default (H+V) RF Pallet Phase Shifter Position
 - Run Power Sense to check Transmit Imbalance measurement. If Transmit Imbalance (i.e., TXB) is between -0.3 to +0.3 dB, then A023 is OK. If outside limits, then run Power Balance for new A023 value.

ZDR Adaptation Data

- A014, A015, and A031 = Suncheck Subtest 1 and Subtest 3 Measurements
 - A014 and A015: Critical for Suncheck Subtest 3 SMB off-line measurements
 - A014 = Azimuth Boresight Correction Factor
 - A015 = Elevation Boresight Correction Factor
 - A031 = SMB, Sun Measurement Bias
- R275 = Baseline System Differential Reflectivity Bias, Used for alarm purposes

Full Calibration or ZDR Calibration

Which do you need to do?

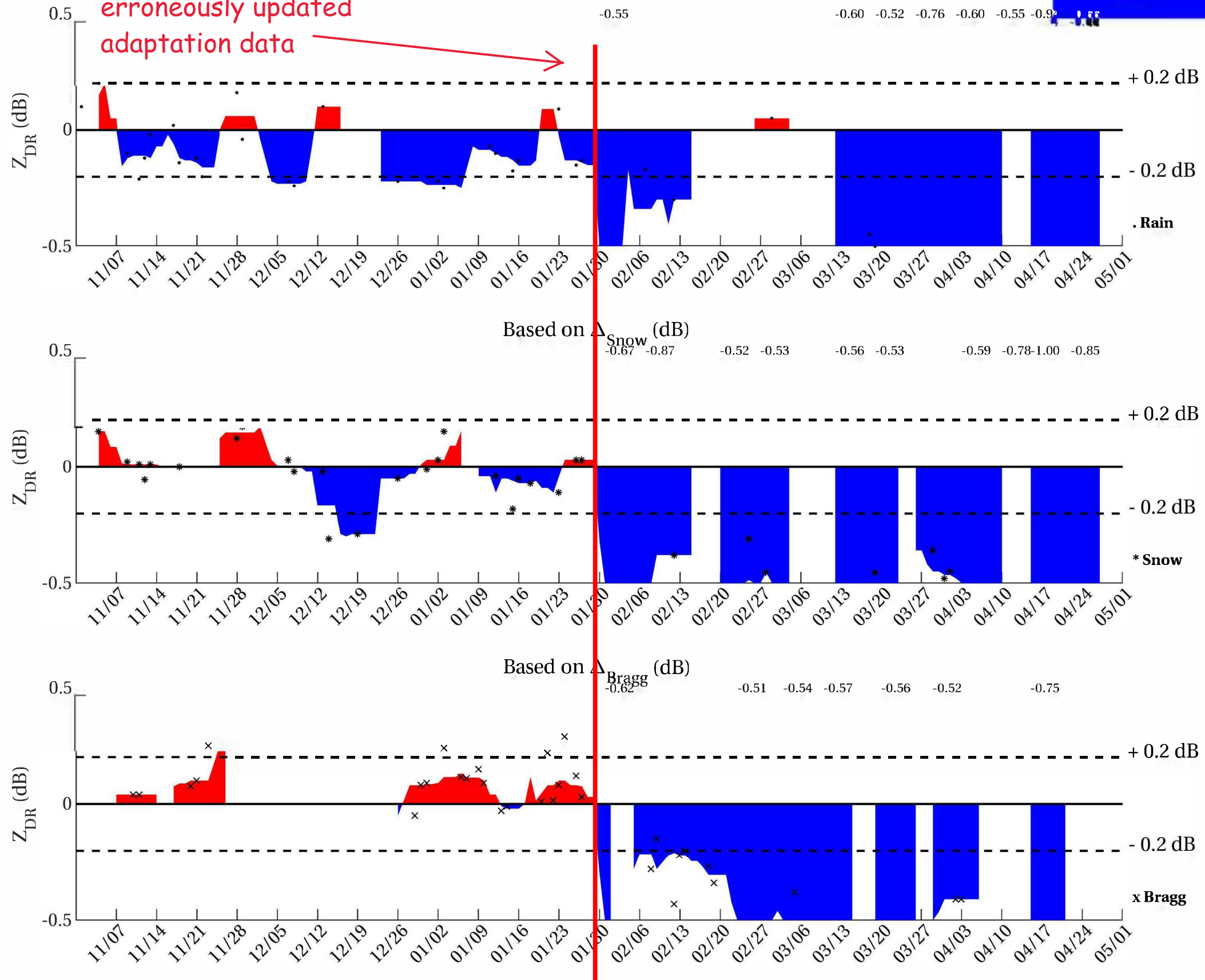
- If ZDR data is out of tolerance (identified by a meteorologist or the ROC) and all other radar parameters appear good, then perform the ZDR Calibration per Table 6-17 Differential Reflectivity (ZDR) Off-line Calibrations.
- What other radar parameters?
 - Dual-Pol Alarms
 - System Noise Temperature
 - On-Line Checks (6.6.3.1) will help you decide if you should proceed
 - Transmitter Power (look at Pulse-Shape & Stability also)
 - System Noise Level
 - H&V I0
 - H&V Linearity
 - H&V Dynamic Range
 - Clutter Suppression Delta

Systematic Z_{DR} Bias (7-day median shading) Nov'18-Apr'19

site performed suncheck and erroneously updated adaptation data

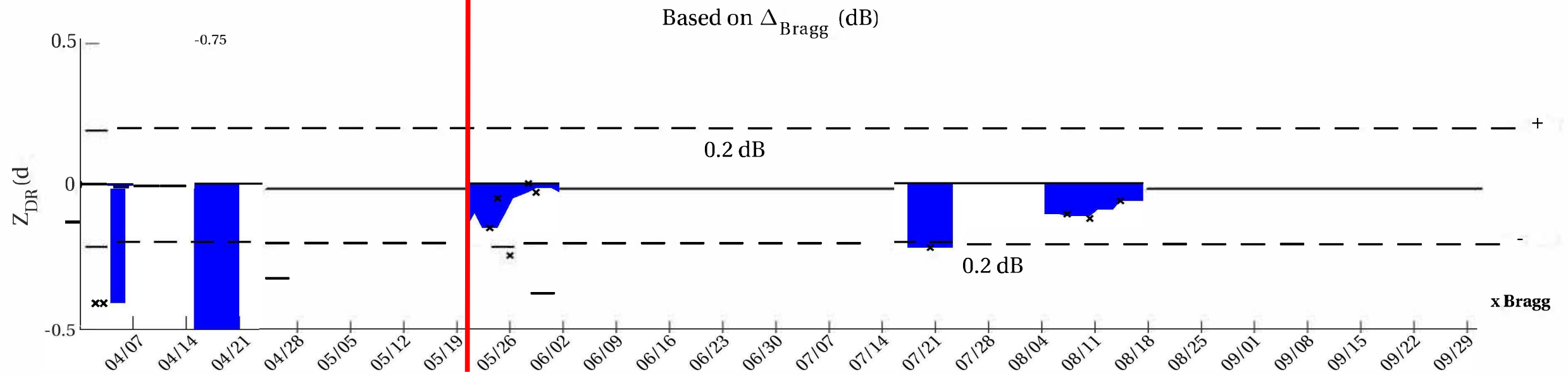
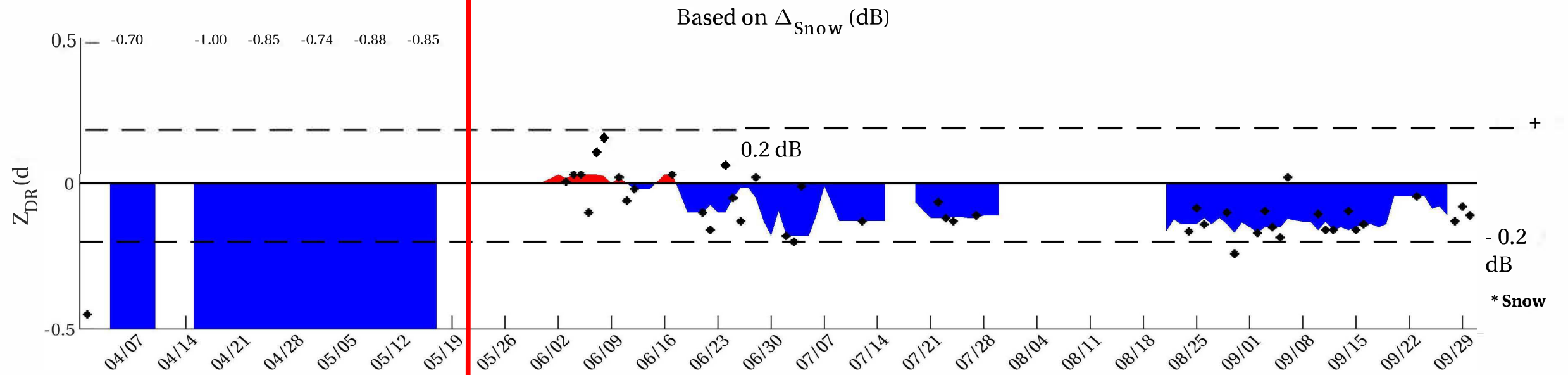
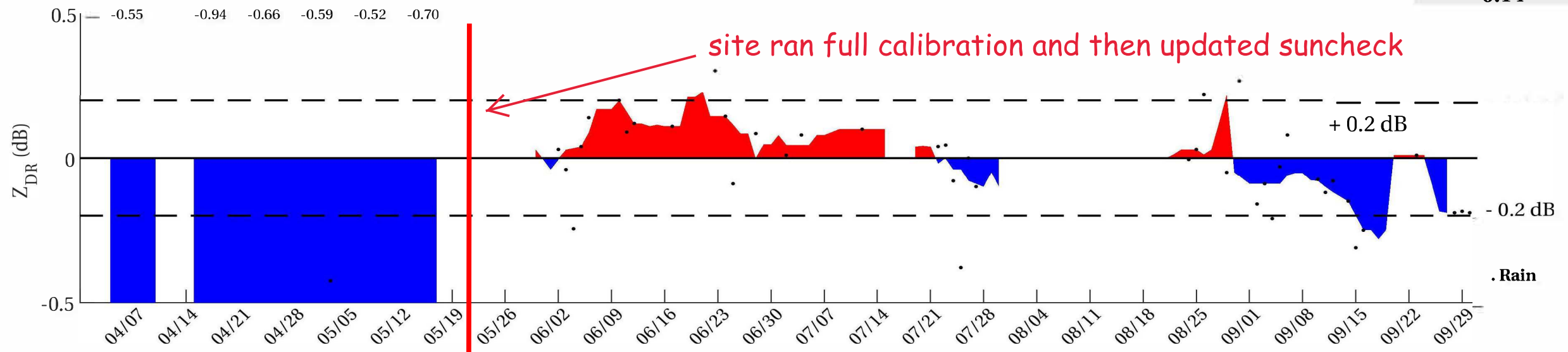
Based on Δ_{Rain} (dB)

Apr'19 WMean (All 3 Methods): -0.61



Systematic Z_{DR} Bias (7-day median shading) Apr'
19-Sep'19 Based on Δ_{Rain} (dB)

Sep'19 WMean
(All 3 Methods):
-0.14



ZDR Shade Chart Info Page:

<https://www.roc.noaa.gov/WSR88D/Operations/Hotline.aspx>

Full Calibration or ZDR Calibration?

- Differential Reflectivity (ZDR) depends upon accurate difference calibrations of the receiver paths, transmit paths, and the antenna.

$$\text{ZDR Offset} = (2 * \text{SMB}) + \text{RCB} + \text{TXB}$$

- For ZDR accuracy, the H and V receiver channels, AME H and V CW test signals, the Transmitter pulse power, and pedestal motion must be stable.
 - The Stability Utility (STS>Calibration>Stability Utility) is useful for checking H and V Receiver paths, CW power, and Transmitter pulse stabilities.
 - Suncheck Subtest 1 is useful for checking pedestal motion stability.

ZDR Calibration Procedure – What Is It?

- The off-line ZDR calibration procedure (Table 6-17), measures the differences between the horizontal and vertical paths in the radar that affect ZDR and updates adaptation data.
- Uses no test equipment
- The order of ZDR Calibration is important because later calibrations rely upon accurate adaptation data from earlier calibrations. See figure 6-22 Sheet 2.

Before you Calibrate...

6.6.3.1 Part 1 - On-Line Checks

- Delta dBZØ is affected by:
 - Transmitter power. Verify the transmitter pulse is stable and peak power is between 650-750KW.
 - Verify the IFDR configuration is correct any time transmitter power / pulse-shape is adjusted.
 - Receiver path gain. Verify there are no noise temperature alarms.
 - Loose cable connections cause issues and alarms.
 - Noise floor: Verify the noise floor is: -82.5 dBm to -83.5 dBm for Short Pulse
-86 dBm to -88 dBm for Long Pulse
 - Intermittent noise level alarms or ZDR alarms may be caused by external interference.

Part 1 - On-Line Checks

6.6.3.1 Power Monitor Check

- Non-invasive On-Line check while radar is producing products
- Simple Transmitter Peak Power check
- If results fall outside the values listed in the procedure, it has you do Fault Note 21, to verify the transmitter output pulse power and shape.

Part 1 - On-Line Checks

6.6.3.2 Performance Data Checks

- Compares adaptation data values from system Noise against current values displayed on the HCI to identify noise issues
- Verifies RADAR Performance Data for:
 - H&V I Naught
 - H&V Linearity
 - H&V Dynamic Range
 - Clutter Suppression Delta

Before you Calibrate...

What Else Should You Check?

- What was done to the RADAR last?
 - At the Training Center almost all issues were items induced during troubleshooting other faults.
- Check all cable connections from the RF Pallet to the IFDR
 - Loose cable connections or poorly aligned QN connectors
 - Over torqued connectors, particularly the SMA QN adapters in BITE Cal
 - The SMA cables in the AME – check for cracks in solder joints if visible
 - The SMA cables in the UD4 cabinet
- Connections from 1AT4 to 4A26 Power Sensor and the IFDR
- Damaged cables/connectors can cause Crossed & Straight to fail

Twisting forces on 90° connector ends of SMA cables causes shield breaks where solder flow ends, sometimes deep under the insulation



Old Style -vs- New Style SMA cables



Attempts to align QN connectors that twist or bend the cable near where the connector clamps to it cause damage to shield and dielectric

- Causes VSWR and signal loss

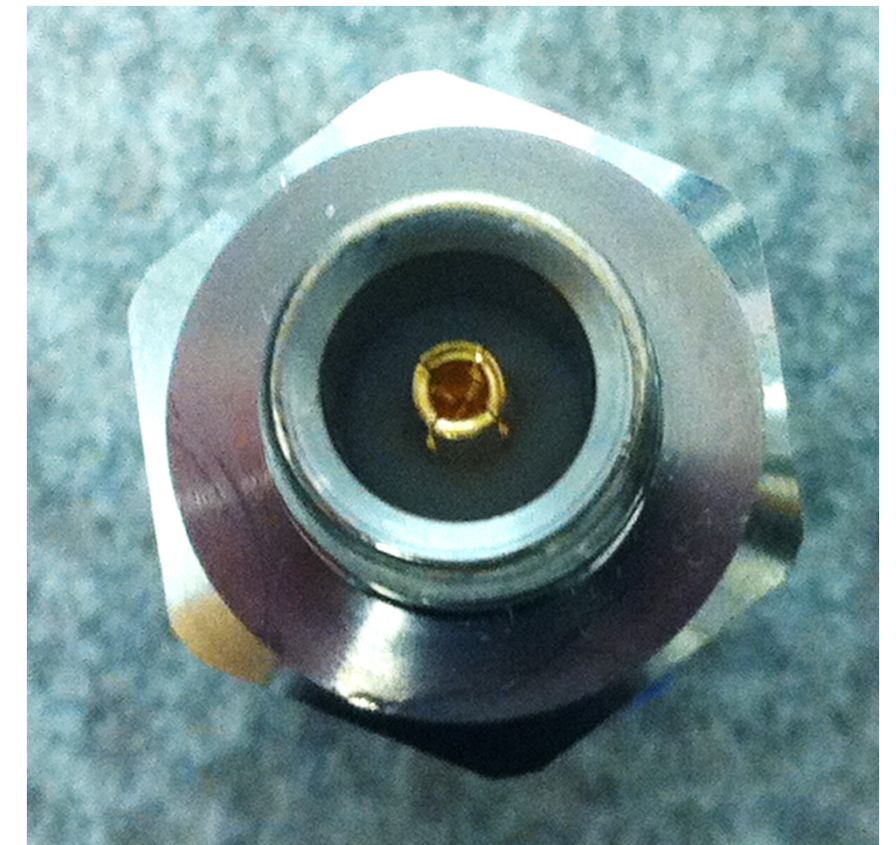


Check that the “cup” of the female pin on N-type connectors should are not spread out from over-tightening

Bad

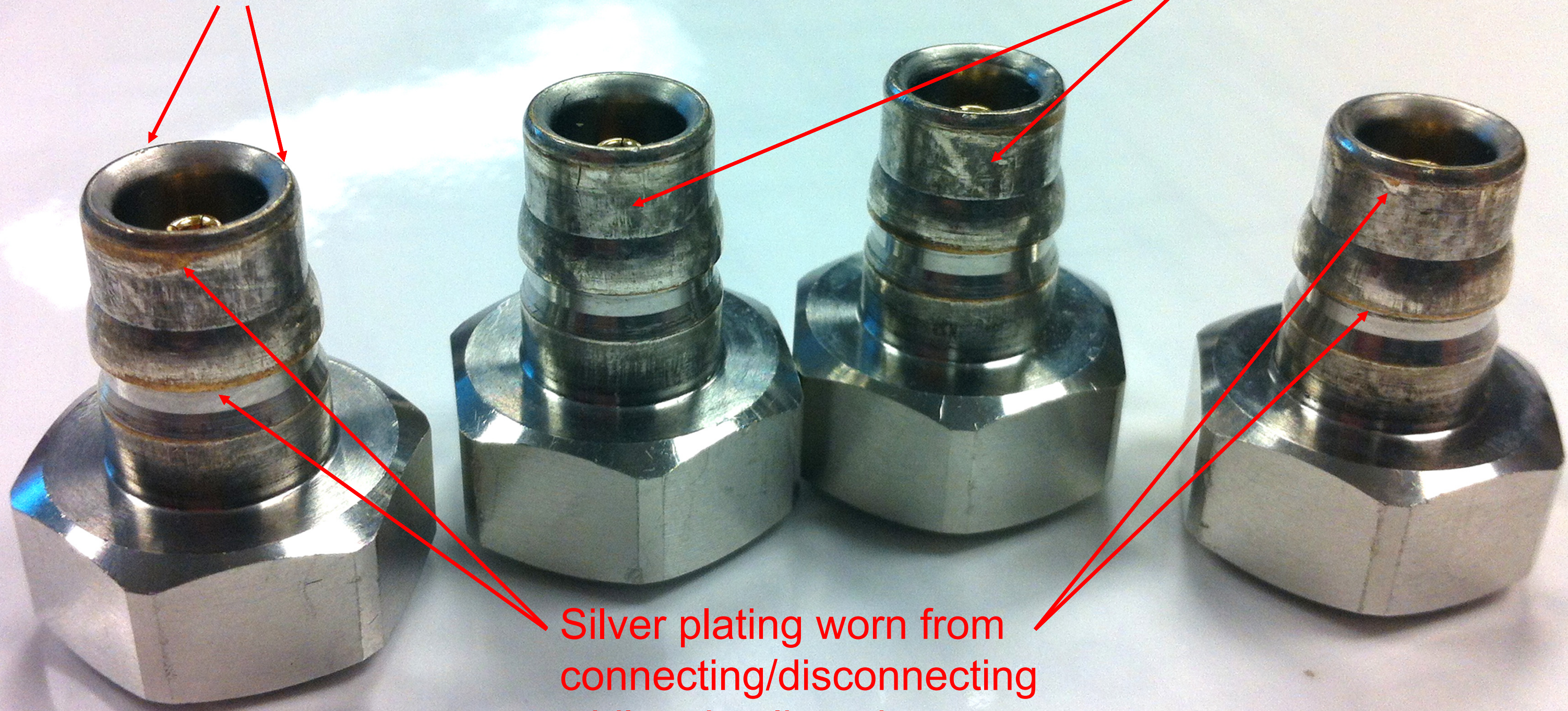


Good



Dents & dings in connector mating surfaces

Silver oxidation



Silver plating worn from connecting/disconnecting while mis-aligned

6.6.3.3 Part 2 - Off-Line Calibration Checks

- If you replaced an LRU complete the calibration procedures listed in Table 6-15.
- If performing a full calibration and no LRUs were replaced, perform the procedures listed in Table 6-16.
 - These procedures must be completed in their entirety and in the order listed and as illustrated in Figure 6-22 sheet 1.
- On redundant systems, calibrations may be run on the controlling channel only. Therefore, complete the required calibration sequence on the controlling channel first. Then transfer control to the opposite channel and repeat the same calibration sequence.

AME CW Test Signal Injection Calibration

- This procedure determines adaptation data values for AME Test Signal Power, R34 (H) and R33 (V).
- This off-line calibration procedure ensures that the H & V AME CW test signal power levels injected into the receiver during automatic calibration are consistent with the adaptation data values used by the automatic calibration routines.

AME CW Test Signal Injection Calibration

- A calibrated medium power sensor, attached through a Type-N bullet adapter and Type-N (F)-to-QN (F) adapter, is used to measure CW t/s power at 2W574 and 2W575.



AME CW Test Signal Injection Calibration

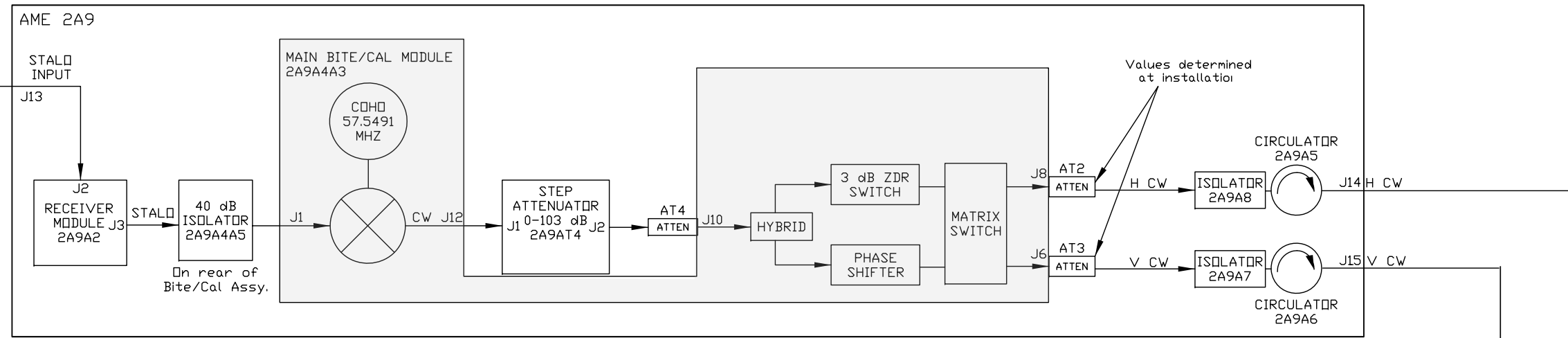
- The procedure consists of stowing the antenna, disconnecting the test signal injection cables at the RF pallet directional couplers, and connecting an RF power meter to the cables.



AME CW Test Signal Injection Calibration

- An off-line test program (AME/Receiver Control) is used to turn on the CW test signal, direct it to the RF pallet, and set the test attenuator to appropriate values.
- It's critical to later calibrations that you get accurate measurements
 - Allow the power sensor to warm-up until the measurement is stable for at least 45 seconds, this takes 3-5 minutes for most 8481A sensors

AME (CW) Test Signal Injection Path

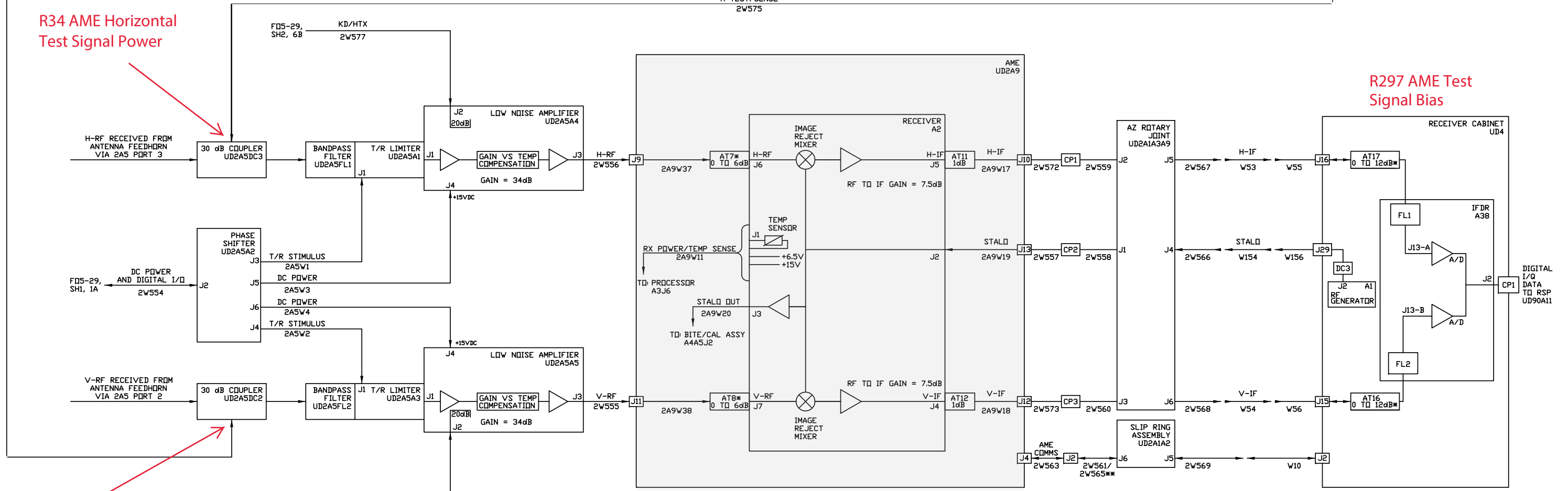


V TEST/SENSE
2W574

H TEST/SENSE
2W575

R34 AME Horizontal
Test Signal Power

R297 AME Test
Signal Bias



R33 AME Vertical Test
Signal Power

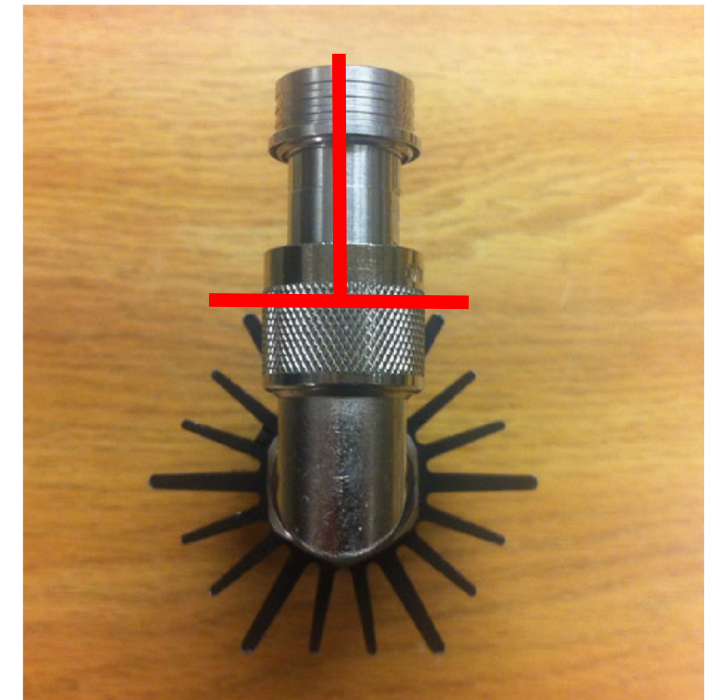
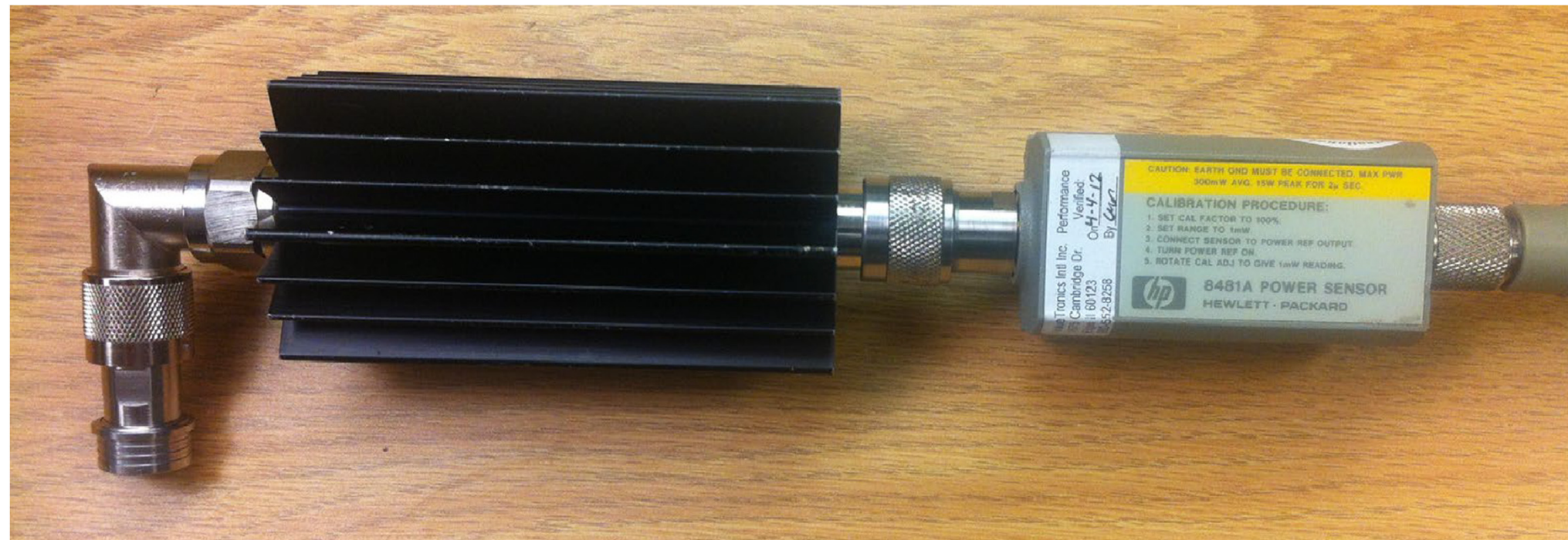
DIGITAL
I/Q
DATA
TO RSP
UD90A11

Horizontal & Vertical Antenna Power (Power Sense) Calibration

- This procedure determines Power Sense Calibration Offsets R286 and R287, and Power Sense Gain Reference R289 from absolute transmitter power measurements, adaptation data, and measurements displayed in Power Sense and Receiver Bias.

Horizontal & Vertical Antenna Power (Power Sense) Calibration

- A calibrated medium power sensor, attached through a High Power 20dB attenuator, Type-N (M-to-F) 90-degree adapter and Type-N (F)-to-QN (M) adapter, is used to measure KD t/s power at 2A5DC2 and 2A5DC3.



Horizontal & Vertical Antenna Power (Power Sense) Calibration

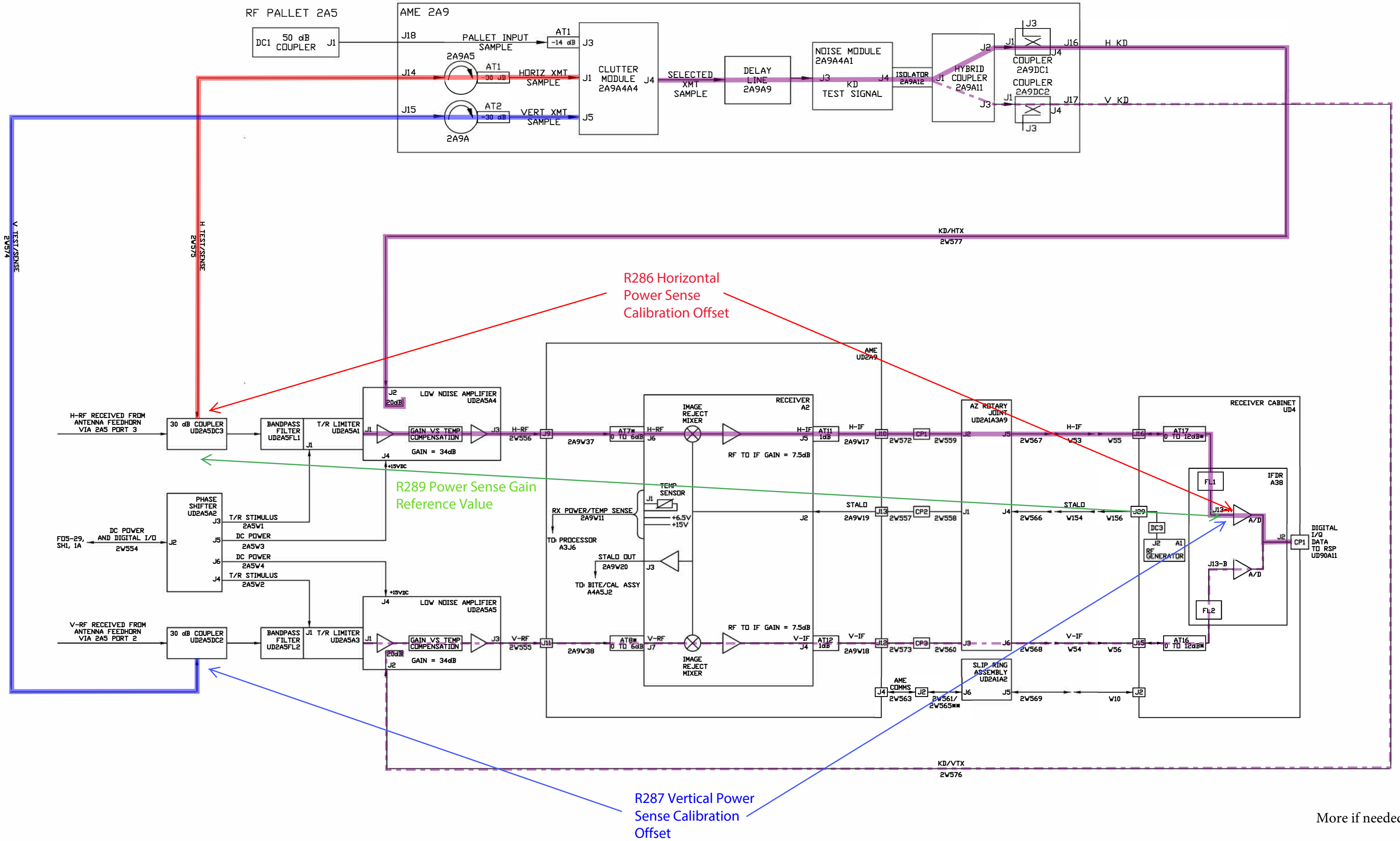
- The STS Calibration Power Sense routine will be used to produce transmitter power at the antenna. Manual measurements of Horizontal and Vertical transmitter power will be made at the RF pallet 30 dB couplers.



Horizontal & Vertical Antenna Power (Power Sense) Calibration

- Then with the system cabling restored to its operational configuration H and V power is routed to the AME, through the delay line and horizontal receive paths to be measured by the IFDR. These measurements will be used to determine Power Sense Calibration Offsets R286 and R287.
- Next the STS Calibration Receiver Bias routine is used to measure the H Power (CW test signal) with the IFDR to determine Power Sense Gain Reference R289.

Power Sense Offset Path



Horizontal & Vertical Antenna Power (Power Sense) Calibration

- The gain of the horizontal LNA is affected by temperature variations in the radome.
- During future on-line calibrations (system calibrate and performance check) Receiver Bias will be measured and compared to R289 to detect fluctuations in the gain of the horizontal LNA that will then be used to correct Horizontal and Vertical Power Sense measurements.

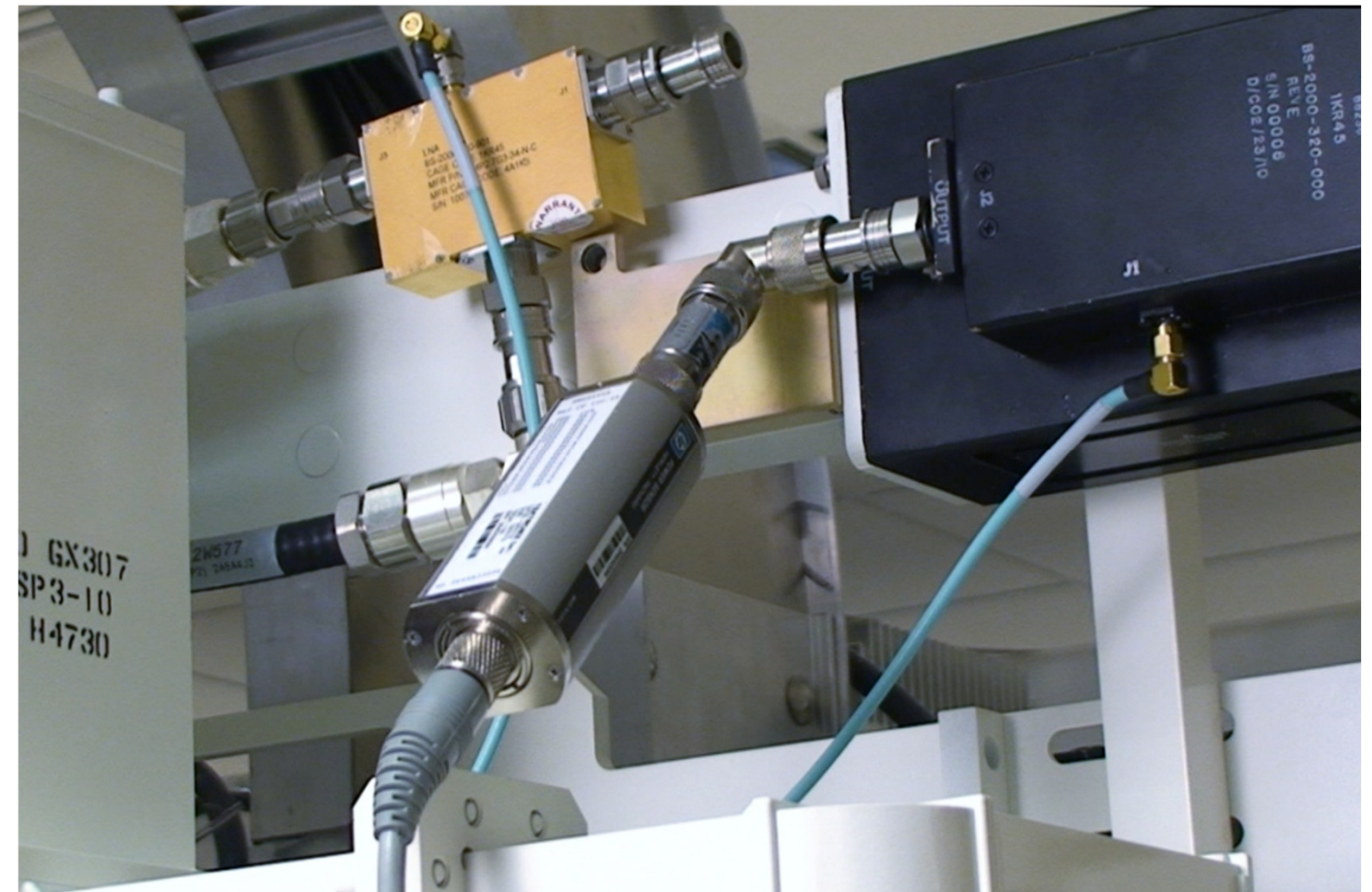
RF Pallet Broadband Loss

- RF Pallet Broadband Loss: R288. A calibrated low power sensor, attached through a 10 dB attenuator, Type-N (M-to-F) 90-degree adapter and Type-N (F)-to-QN (M) adapter, is used to measure CW t/s power at Horizontal T/R Limiter 2A5A1J2.



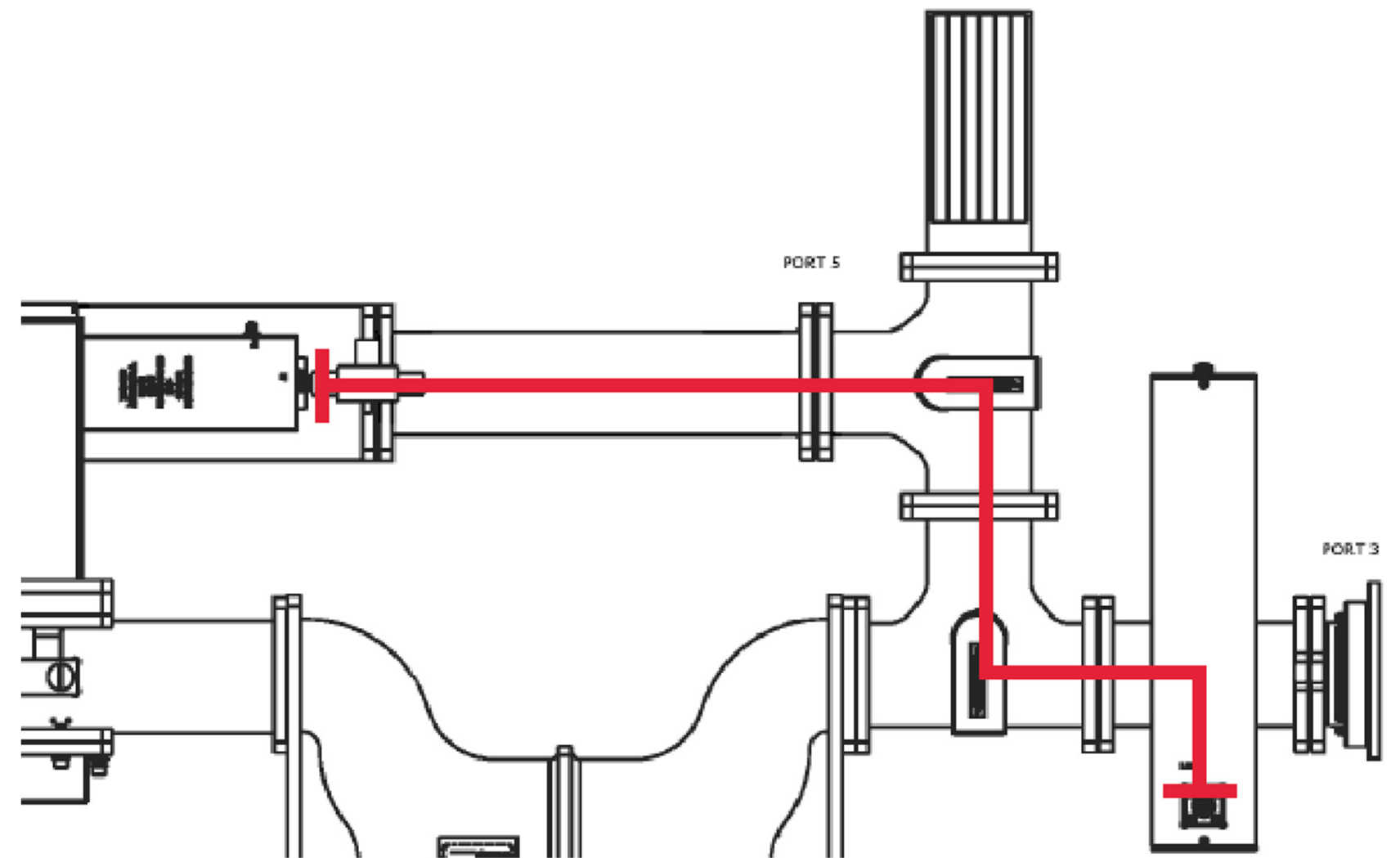
RF Pallet Broadband Loss

- Off-line test program STS/AME/Receiver Control is used to turn on the CW test signal, direct it to the RF pallet, and set the test attenuator to appropriate values.
- Three measurements are taken at the output of the TR limiter and averaged



RF Pallet Broadband Loss

- AME Horizontal Test Signal Power R34 (determined earlier), is used as the input power level to calculate the loss between Horizontal 30 dB Coupler 2A5DC3 and Horizontal T/R Limiter 2A5A1J1.



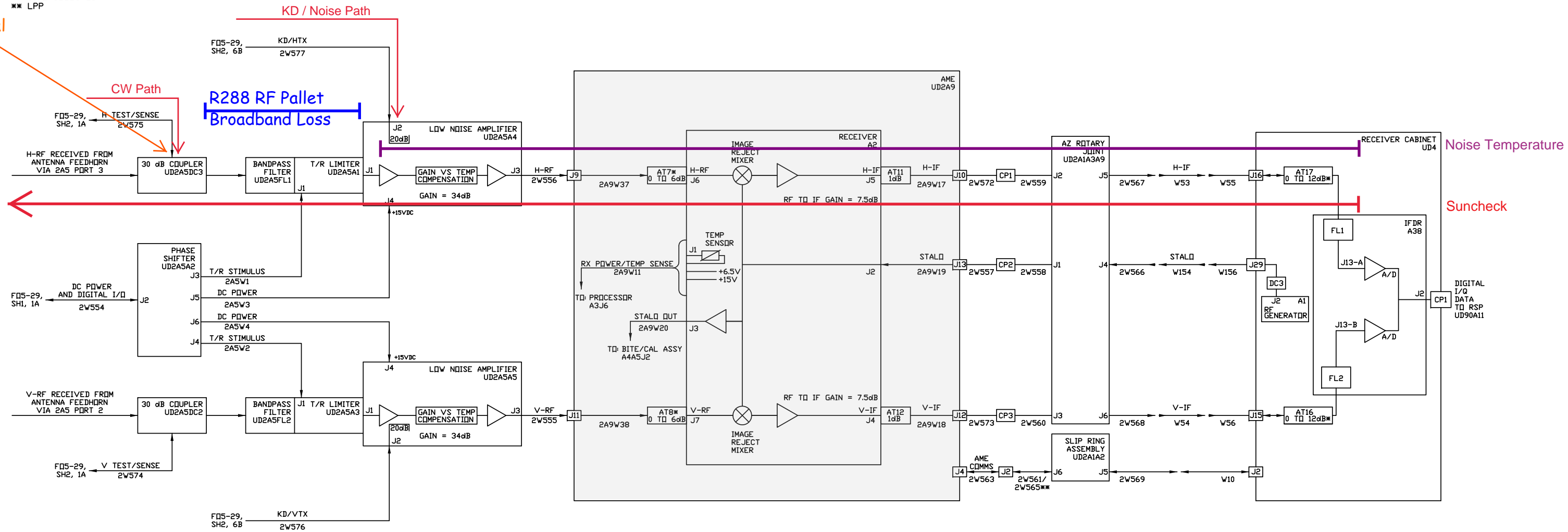
RF Pallet Broadband Loss

- Only the horizontal channel is measured in this test.
- R288 is the pathloss between 30 dB Coupler 2A5DC3 and the input to the H-LNA.
 - Used in determining System Gain Estimate in Suncheck Measurement subtest 2.
 - For more on Suncheck see EHB 6-513 (5.17.4)
- R288 is expected to be between -1.1 dB and -0.7 dB, with values outside that range typically due to calibration (6.6.3.3.9) or hardware issues.
 - Lower R288 values (for example, -.6 dB) are unrealistic and typically indicate a calibration issue.
 - R288 values greater than -1.1 dB can be caused by hardware problems in the waveguide components between the 30 dB coupler and the LNA.

SINGLE CHANNEL SYSTEMS

R34 AME
Horizontal
Test Signal
Power

NOTES:
* SITE SELECTED
** LPP



NX3853-E

Figure 5-1. Receiver Signal Flow Block Diagram (Sheet 1 of 3)

RF Pallet Broadband Loss - Note

- In Suncheck Subtest 2 Suncheck procedure (6.6.3.7.1):
“It is essential that all previous calibrations relating to R288, RF Pallet Broadband Loss (6.6.3.3.9), and R35, AME Noise Source calibration (6.6.3.3.10) be checked prior to doing the Suncheck Measurements Subtest 2 procedure.”

...I suspect this was meant to say before you place significant value on the results of Suncheck Subtest 2. - JEB

AME Noise Source Calibration

- The site must borrow Noise Source Calibration Kit ASN R400-SE44-1 (NSN 6625-01-496-1495) from shared support equipment

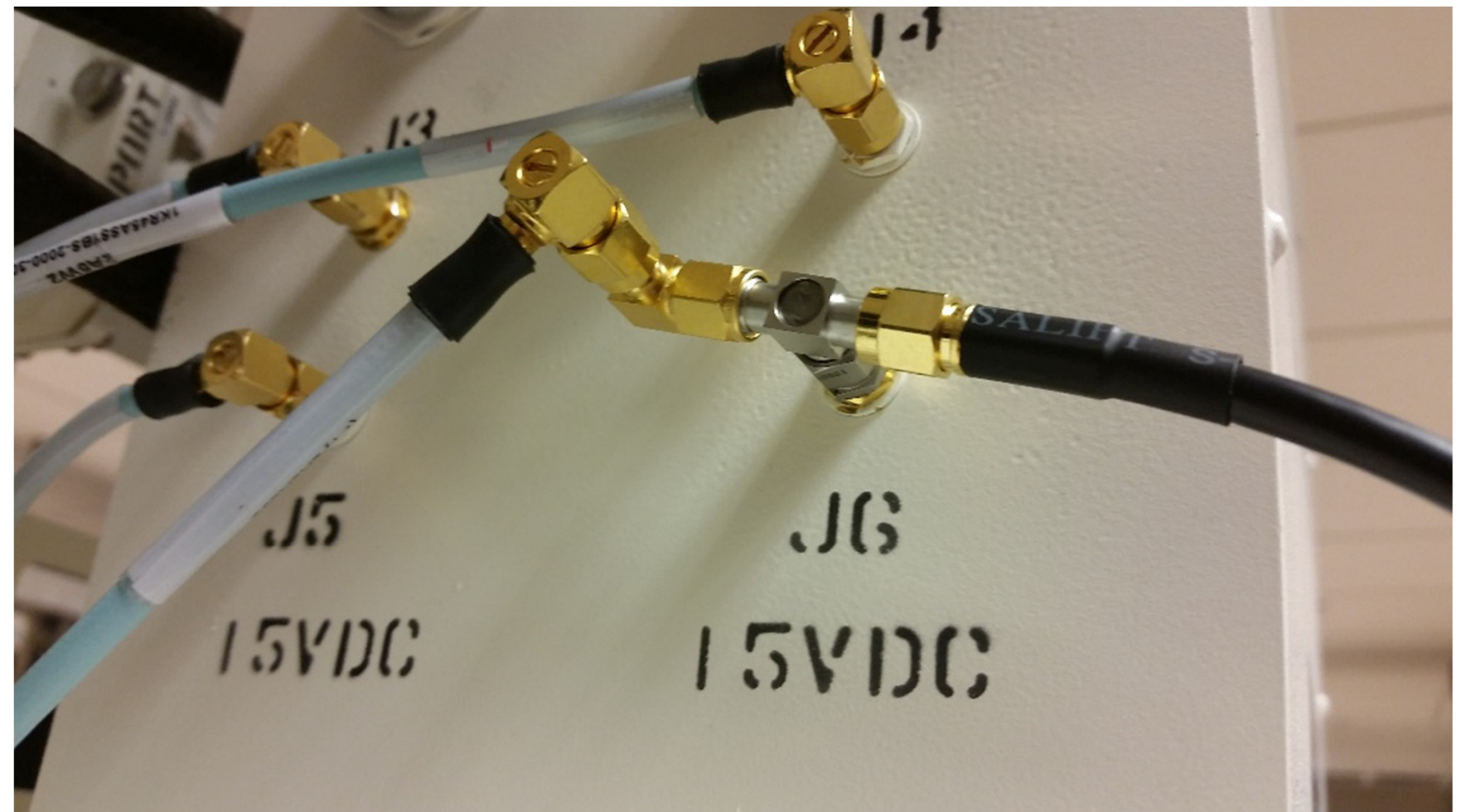


AME Noise Source Calibration

- Determines the AME Noise Source Excess Noise Ratio (ENR) value for horizontal (R35) and vertical (R299) channel, referenced to a point within each particular LNA.
- Ensures the validity of the horizontal and vertical system noise temperature measurements.

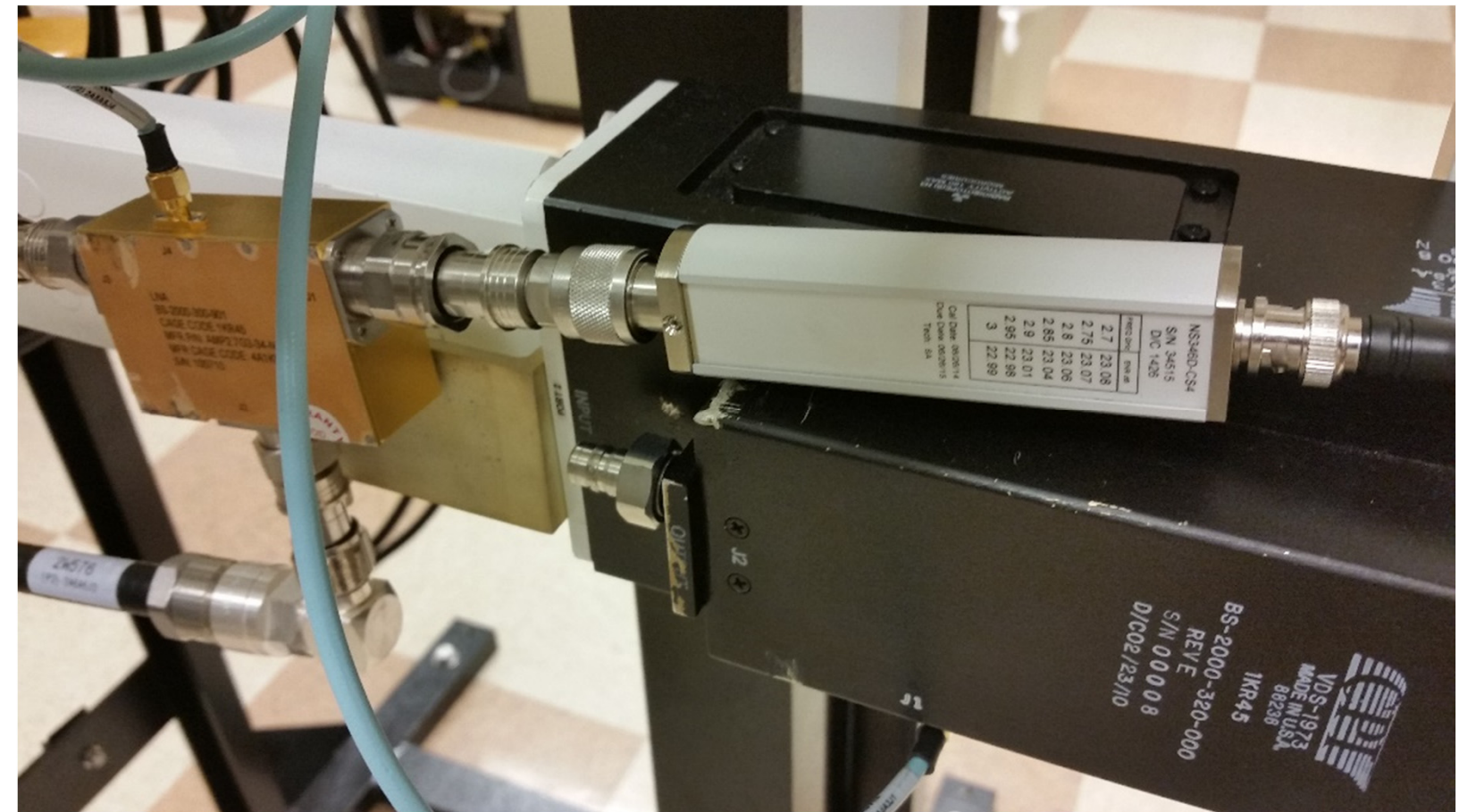
AME Noise Source Calibration

- The Noise Standard's power cord is connected to J6 of the RF Pallet Phase Shifter.
- Note: Be careful that you do not over torque this connection as loosening it can brake loose the bulkhead connector on the phase shifter creating a waveguide pressure leak.



AME Noise Source Calibration

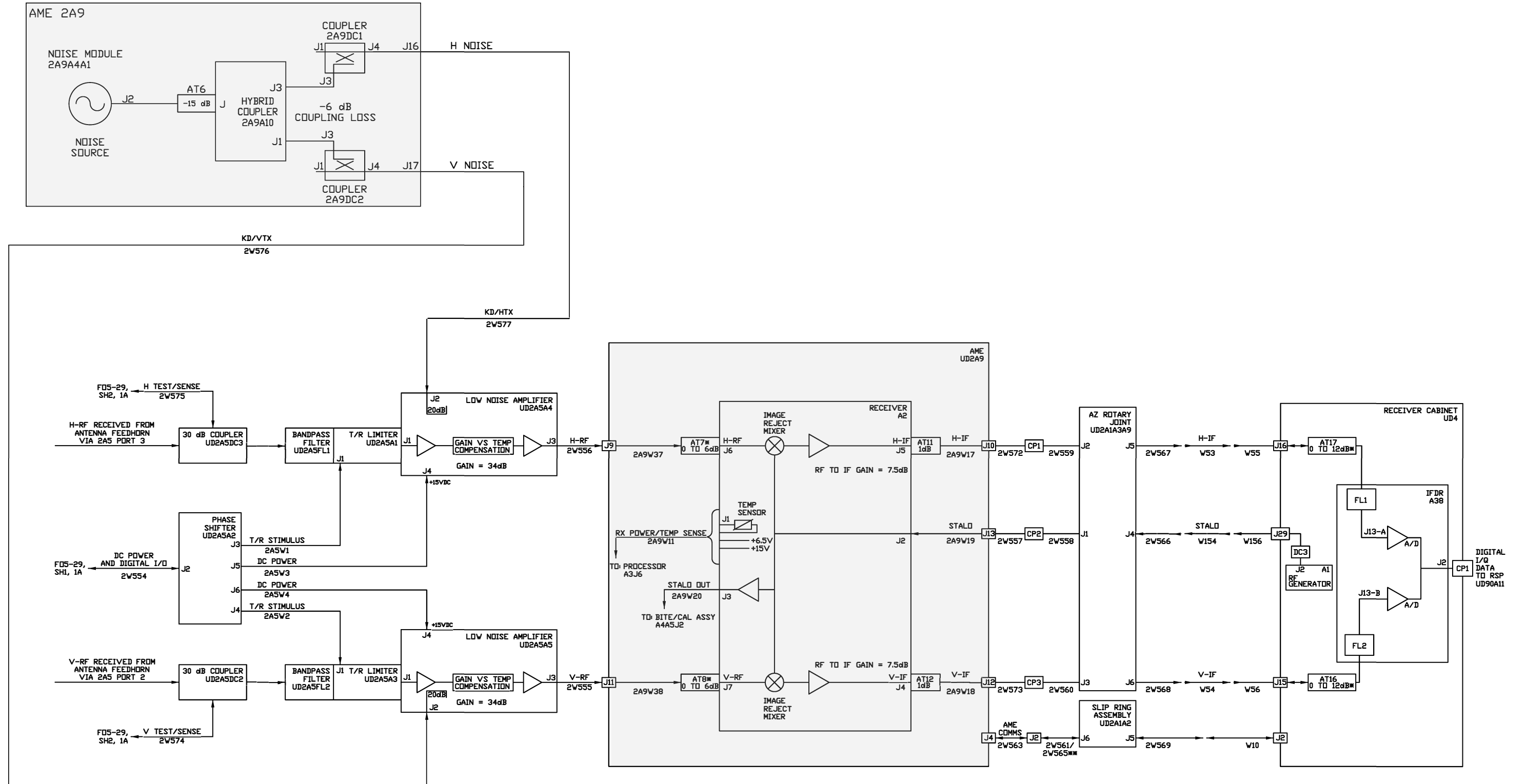
- Calibration involves injecting a calibrated Noise Standard (with known site-frequency ENR) into each LNA and recording the noise power measured at the IFDR using the STS Noise Level routine.



AME Noise Source Calibration

- A reference is established using these measurements and the ENR of the Noise Standard.
- Then, with both LNAs attached in the normal configuration, the AME noise source is simultaneously injected into each LNA and the H & V noise-on power is measured at the IFDR using the STS Noise Temperature routine.
- New AME Noise Source ENR values are calculated and entered into adaptation data.

Noise ENR Path



Crossed and Straight Calibration

- Determines R297 AME Test Signal Bias and R298 Power Sense Calibration Offset Bias which are critical to ZDR calibration
- Provides test signal consistency checks between Power Sense Test Signal and AME Test Signal calibration to confirm CW calibration is sufficient to ensure reflectivity accuracy.

Crossed and Straight Calibration

- Power Sense uses R298 Power Sense Calibration Offset Bias (and R295 and R296) to calculate Transmit Imbalance from IFDR measurements.

Crossed and Straight Calibration

- Initially in this measurement, the horizontal and vertical test/sense cables are connected in a *crossed* configuration; then Power Sense and Receiver Bias measurements are recorded.
- Then the connections are put back in the normal, *straight* configuration and new Power Sense and Receiver Bias measurements are recorded and R297 and R298 are calculated.
- After R297 and R298 are determined, adaptation data updated and the RDASC restarted, the Power Sense calibration routine is run to determine tr34 Transmitter Bias (TXB) Baseline; tr34 is used for alarm purposes and should only be updated after successfully completing a Crossed and Straight Calibration.

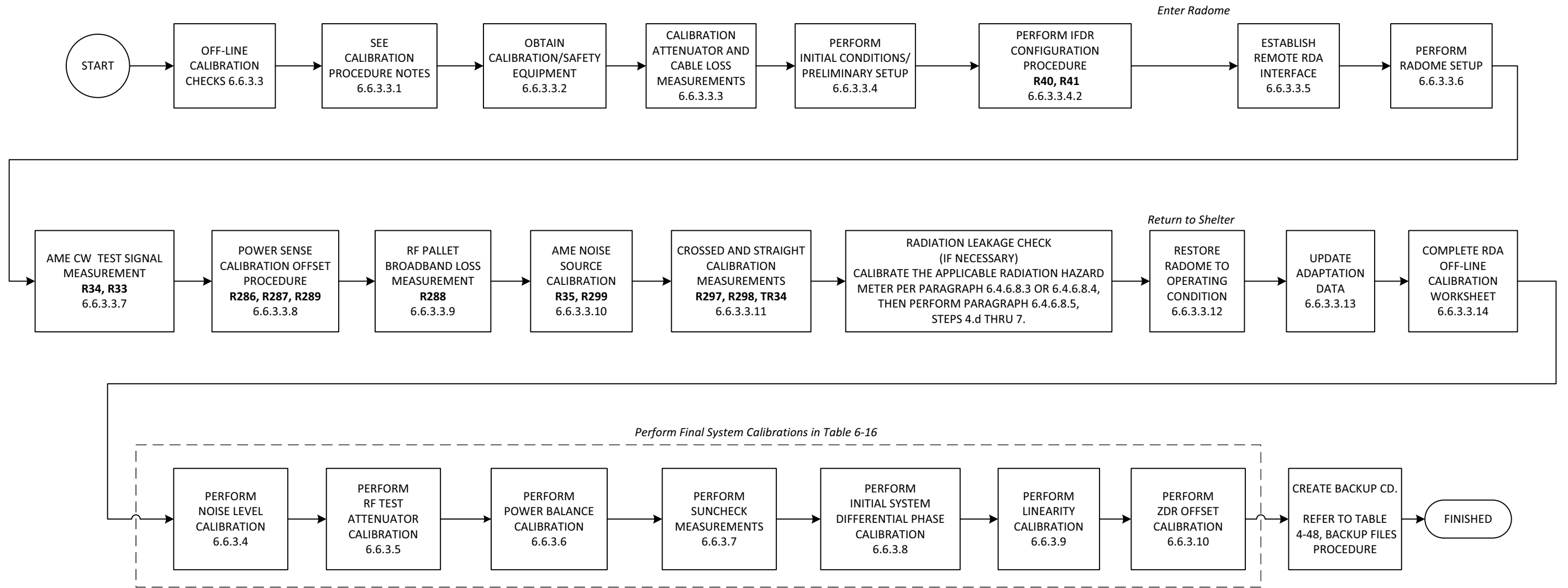
Crossed and Straight Calibration - Note

- In Suncheck procedure (6.6.3.7.1):

“It is essential that the Crossed and Straight Calibration Measurements procedure (6.6.3.3.11) has been recently performed (and the measurements passed with the adaptation data updated and RDASC restarted) prior to doing Suncheck Measurements Subtest 3”

...I suspect this was meant to say before you run Suncheck with the intent of updating the adaptation data determined by Subtest 3. - JEB

FULL CALIBRATION PROCESS



NOTE: FOR ZDR CHECKS AND CALIBRATION, SEE SHEET 2

Figure 6-22. Integrated Calibration (Sheet 1 of 2)

Questions?