10/25/2004

Station RF Controller
Calibration Procedure

S/N # 003.

1.) Check and Adjust Power Supply ☒

Make sure that a 50 Ohm terminator is placed on the RF input and output of the VGA (ZFL-1000 GH) before power is applied. No load on the output of the VGA can result in damage to the VGA. Terminate all RF connections not being used.

Unplug the Power Connector to both the RF Board and the Analog Board. Plug in the AC cord and adjust the Power Supply adjustment pots for +/- 15 V on its outputs.

2.) Check the Linearizer P.S. Input Voltages ☒

Make sure P.S. voltages are correct at the linearizer. (+5 V, +15 V, -15 V)

3.) Apply Power to the Analog Board and Check P.S. Voltages ☒

Plug in the P.S. connector to the Analog Board.

Ensure that the +10V Reference voltage is present by probing Pin 2 of the voltage reference U6. ✓

Ensure that the +5 V regulator output is present at Pin 3 of U23. ✓

Ensure that the Front Panel (F.P.) +/- 15 V LED's are lit. ✓

Ensure that +/- 15 V appears at the F.P. P.S. test points. ✓

4.) Check Analog Board RF Output Gate Functionality ☒

Connect a 50 Ohm terminator to the Rear Panel (R.P.) "RF Output Inhibit 1" and "RF Output Inhibit 2" inputs. When this is done, the F.P. "RF Out Gate Control 1" and "RF Out Gate Control 2" LED's should be lit. Disconnecting the terminator from inputs 1 and 2 should cause the respective F.P. LED's to turn off. ✓

Ensure that P6 – Pin1 (probe underside of board) of the RF Board changes state with and without the terminator on either of the inhibit inputs. Check both. LED's ON = 0V at P6, LED's OFF = 5 V. ✓

Station RF Controller Drawings

9532.000-ED-182026 Block Diagram

9532.000-ED-181994 RF Board Schematic

9532.000-ED-182018 A/D Processing board Schematic

Station RF Controller
Calibration Procedure

5.) Check Analog Board RF Input Gate Functionality ☒

Place a 50 Ohm terminator on both RF Output Inhibits 1 & 2 on the R.P. Connect a +5 V source to the R.P. "RF Input Inhibit". Verify that the F.P. "RF Input Gate" LED lights up. ✓

Verify that appropriate signals change logic level with a change in the +5 V source to 0 V. These signals are at transistor location Q1 – Pin 2 (yellow wire) on the analog board and at P2 – Pin 1 on the RF Board. +5 V at the source = 0 (low) logic level at both locations. 0 V at the source = 1 (high) logic level at both locations. ✓

6.) Check the functionality of the Linearizer's RF Drive Program ☒

Place a 50 Ohm terminator on both RF Output Inhibits 1 & 2. Connect the +5 V source to the RF Input Inhibit. ✓

Connect a 0 to 10 V source to the R.P. "RF Drive Program Input". Probe the VGA control voltage and ensure that it follows changes in the 0 to 10 V source as expected from the linearizer (0 V in = ~2V out, and 10 V in = ~0 V out). ✓

7.) Verify the functionality of the R.P. Reference Voltage Output ☒

Probe the R.P. "Ref. Voltage Out" and ensure that the output changes appropriately when the F.P. "Ref. Volt Adjust" is adjusted.

8.) Verify the functionality of the RFCQG Program Input ☒

Apply a 0 – 10V supply to the R.P. "RFCQG Prg." Input.
Probe the F.P. "RFCQG" test point. For 0 V in the RFCQG should have an offset (~9 V). Apply a small voltage (0 – 2 V) at the "RFCQG Prg." Input and ensure that the F.P. test point changes.

9.) Prepare for powering up the RF Board for the first time

Terminate all of the RF output connectors with Kings 50 Ohm terminators.

Place a 50 Ohm terminator on the input to J1.

Terminate SMA connectors J3 and J4 with 50 Ohm terminators.

Ensure all Front Panel RF monitors have their 50 Ohm terminators plugged in.

Terminate J6 and J7 with 50 Ohm terminators.

Terminate all R.P. RF Input connectors with 50 Ohm terminators.

10.) Apply power to the RF Board and check supply voltages.

Power down the Station RF Controller module.
Plug in the P.S. connector (P7) to the RF Board.
Plug the AC power cord back in and check the RF Board P.S. voltages: +/- 15 V, + 5V and – 5V. (+/- 5V can be checked at the voltage regulator outputs, Pins 3 of U25 and U26.)

11.) Calibrate the RF FB Program Gain.

Connect the R.P. "Ref. Voltage Out" to the R.P. "Loop Gain Prg." Input.

Probe the R.P. "Ref. Voltage Out" connector and adjust the F.P. "Ref. Volt Adjust" potentiometer for 3.5 V at the probe.

Probe the F.P. "RF FB Loop Gain" test point and adjust the F.P. "RF FB Prg. Gain" on the Analog Board until the test point matches the 3.5 V Ref. Voltage Out. This adjusts the initial Loop Gain Prg. Input for unity gain.

12.) Set the initial "Drive + Error Limit Level"

Probe the F.P. "Limit Level" test point and adjust the F.P. "Drive + Error Limit Level" potentiometer until the test point is at 8.0 V.

Station RF Controller
Calibration Procedure

14.) Calibration of RFCQG offset and Program input

With 0 V at the R.P. "RFCQG Prg." Input:
On the Analog Board, probe test point T2.
Adjust R10 until T2 is at - 9.1 V.
With 9.1 V at T2, adjust the F.P. "RFCQG Cal" potentiometer until the F.P. "RFCQG Prog" test point reads 9.0 V.

Now apply –2.00 V at the R.P. "RFCQG Prg." Input:
Adjust the F.P. "RFCQG Gain" potentiometer until the F.P. "RFCQG Prog" test point reads 6.5 V. This adjust the initial RFCQG Program gain to 1.25 while simultaneously setting the initial RFCQG offset to 9.0 V.

Disconnect the input to the R.P. "RFCQG Prg." Input. The F.P. "RFCQG Prog" test point should read 9.0 V for the remaining RF Board calibrations.

Station RF Controller
Calibration Procedure

RF Board
RF Path Measurements and Calibrations

Note: The NWA calibration plane should consist of - Port 1 : N-male
Port 2: N-female

15.) Measure the gain from J7 to the RF Outputs ☒

Terminate the following connections in 50 Ohms:
Input cable to J1, J3, J4, J6,
Direct RF FB Input, RF Feed Forward Input, All RF Outputs,
VGA (ZFL-1000GH) input and output

Perform a Thru Response calibration on the NWA.
NWA Settings: 1601 Pts. IF BW: 3 kHz
Center Freq: 53 MHz Span: 20 MHz
Pwr: -10 dBm

Connectors used: **Port 1: (N-female to SMA-male)**
Port 2: (N-male to BNC-female)
and (BNC-male to BNC-male)

Ensure that all RF Outputs are functioning and are balanced in both amplitude and phase. Physically disturb the output cables to ensure that there aren't any bad or intermittent connections.

The nominal gain from J7 -> RF Out #1 = 4 dB

16.) Measure and Adjust the RF Feed Forward path gain ☒
R.P. "RF Feed Forward" -> R.P. RF Out #1

Connectors used: **Port 1: (N-female to BNC-male)**
Port 2: (N-male to BNC-female)
and (BNC-male to BNC-male)

Ensure all unused RF connections are terminated in 50 Ohms.

Insert a 2dB attenuator and the J6 -> J7 cable between J6 and J7.

NWA Source Power: -10 dBm
Measure the gain from the RF Feed Forward input -> RF Out #1.
The gain is nominally 10.3 dB
Adjust the RF attenuator if necessary to comply with the nominal value.

17.) Tune the RF Feed Forward path delay

Adjust the length of the Feed Forward input cable for a nominal electrical delay of ***8.864 ns*** at 53MHz from R.P. "RF Feed Forward" -> R.P. RF Output 1. Use the same NWA settings as in steps 15 and 16. Ensure that the NWA Phase Offset is set to 0 deg.
(RG316 and M17/152 cable typically exhibit ~121 ps/inch)

18.) Calibrate the Direct RF FB path delay
Direct RF FB -> RF Out #1

Connectors used: **Port 1: (N-female to BNC-male)**
Port 2: (N-male to BNC-female)
and (BNC-male to BNC-male)

Ensure the following RF connections are terminated in 50 Ohms:
RF Feed Forward input
J3 & J4
RF Outputs
ZFL-1000GH input and output

Connect the R.P. "Ref. Voltage Out" to the R.P. "Loop Gain Prg." Input. Adjust the F.P. "Ref. Volt Out" so that the F.P. "RF FB Loop Gain" test point is 3.5 V.

The Station RF Controller settings should be:

RFCQG = 9.0 V
Drive + Error Limit Level = 8.0 V
RF FB Loop Gain = 3.5 V

The NWA Source Power should be reduced to –25 dBm.
The NWA Phase Offset should be set to 180 deg.

Adjust the Direct RF FB input cable length for a nominal electrical delay of ***11.831 ns*** at 53Mhz with a nominal gain of ~10 dB.

19.) Calibrate the electrical delay of cable J3 -> J4

The RF Drive path and the RF Error path need to have the same electrical delay. The cable between J3 and J4 is in the RF Drive path and is to be used to match the RF Drive path delay to the RF Error path delay.

Connectors used: **Port 1: (N-female to SMA-female)**
Port 2: (N-male to SMA-male)

First measure the RF Error path delay:

- Terminate connections J3 and J4 with 50 Ohms.
- **Make sure the R.P. "Direct RF FB" input is terminated in 50 Ohms also.**
- Ensure that the NWA is calibrated. Use the same frequency settings as in previous steps.
- Set the NWA power level to –25 dBm.
- Set the Station RF Controller settings to:
    - RFCQG = 9.0 V
    - Drive + Error Limit Level = 8.0 V
    - RF FB Loop Gain = 3.5 V (use R.P. "Ref. Voltage Out")
- Measure the phase of s21 between J1 and J6.
- Adjust the NWA internal electrical delay to determine the electrical delay of path J1 to J6 at 53 MHz. Use a NWA Phase Offset of 180 deg for this measurement.
- Store the data to memory and set the NWA to display both data and memory.

Measure and adjust the cable between J3 and J4.

- **Unplug the R.P. "Ref. Voltage Out" from the R.P. "Loop Gain Prg." Ensure the the "RF FB Loop Gain" is off (0 V)**
- Adjust the NWA source power to –20 dBm.
- Connect the J3 to J4 cable between J3 and J4.
- Keep the NWA connected to J1 and J6.
- Measure the electrical delay at 53 MHz. The NWA Phase Offset should remain at 180 deg for the measurement.
- Adjust the length of the cable between J3 and J4 to match the electrical delay of this path at 53 MHz to the RF Error path data stored in memory. The data trace and the memory trace should intersect at 53 MHz when the cable tuning is complete.
- Print the results showing both the memory and data trace

20.) Calibrate the VGA Linearizer and the RF IN -> J3 path gain and delay ☒

Prepare to measure the gain of the RF IN -> J3 path as a function of the "RF Drive Prg." Input control voltage. This path includes the VGA and thus requires a calibration of the VGA linearizer and the input attenuators on the R.P. "RF Input".

Connectors used: **Port 1: (N-female to BNC-male)**
Port 2: (N-male to SMA-male)

- On a Tektronix digital oscilloscope (a TDS 3034B), recall the supplied reference file waveform data to a reference waveform memory location.

  The supplied files are as follows:

  - Prg_IN.ISF = a typical 0 to 11V triangular waveform applied to the R.P. "RF Drive Prg." Input.
  - Lin_OUT.ISF = a typical linearizer response to the 0 to 11V triangular waveform input. ✓
  - Connect a scope probe to the Linearizer's output. A convenient location to probe this is at the VGA's "AGC" control voltage input.

    - Ensure that a Signal Path Compensation calibration has been performed recently on the Tektronix Scope.

- Set up a waveform generator (using a Wavetek Model 184 is described here)
  - Match the waveform generator's output to the reference file waveform from Prg_IN.ISF in both amplitude and frequency.
  - Connect the waveform generator's output to both the Station RF Controller's R.P. "RF Drive Prg." Input and the oscilloscope. ✓
  - Connect the generator's pulse output to both the NWA's external trigger input and Ch 4 of the Tektronix scope. Set Ch 4's coupling to 50 Ohms.
  - Set the Tektronix scope to trigger off of Ch4 wish a negative slope.

Station RF Controller
Calibration Procedure

- Set up the NWA (HP 8753E)
    - Using the supplied reference files, recall the NWA state file "***INtoJ3***". This will set the NWA into a CW Freq sweep mode and loads in an example data set resulting from a Linearizer calibration. The NWA trigger status will be loaded into a HOLD state.
    - Upon loading the NWA state file the example data exists in both the data trace and the memory trace. The memory trace will be used as the reference data to which the newly acquired data will be matched.
    - Set the NWA source power to +7 dBm.
    - Perform a NWA calibration
        - Turn on the source power
        - Set the NWA Trigger to CONTINUOUS mode and set the trigger to INTERNAL
        - Use 8x averaging during the calibration
        - Confirm a successful calibration
    - Turn OFF the NWA source power
    - Set the NWA trigger mode to CONTINUOUS mode and set the trigger to EXTERNAL
    - Keep the Station RF Controller powered OFF until the NWA connections have been made to J3 to ensure that a stable load is presented to the VGA output.
    - Connect the NWA between the R.P. "RF Input" port and J3 on the RF Board. (Port 1 to the "RF Input" and Port 2 to J3.)

- Install initial attenuators along the RF Input path
    - The cable between the "RF Input" and the VGA input is a cable whose electrical delay will also be tuned. Thus it begins as a cable with one of its connectors not crimped. Use this cable carefully.
    - Initially insert 3 attenuators between the R.P. "RF Input" and the BNC end of this cable. The attenuators will be attached immediately on the inside of the rear panel at the "RF Input" feedthrough. The 3 initial values to begin with are a 20 dB, a 3 dB, and a 2 dB.
    - The 2 dB may need to be changed to either a 1 dB or a 3 dB to help achieve the best calibration during the calibration of the linearizer.

Station RF Controller
Calibration Procedure

- Initial measurement and calibration of the Linearizer
  - Initially the linearizer will be roughly adjusted along with the attenuator pads to roughly match the memory trace. This initial adjustment is to find the final attenuator values which will be needed and to get the linearizer close to its final state. Once the initial adjustment is made, the input cable which is used to adjust the electrical delay of the RF Input path will be tuned.
  - Power up the Station RF Controller
  - Ensure that the linearizer's input ("RF Drive Prg." Input) matches the reference trace. Ensure that the linearizer's output rougly also matches its reference trace.
  - Turn on the NWA source power.
  - Measure s21 in Lin Mag format and calibrate the Linearizer. Match the VGA response to the memory trace as closely as possible. However keep in mind that a final calibration will be performed once the input cable has been adjusted for the electrical delay. Use the following potentiometers to adjust the Linearizer:
    - R9 - adjusts the offset of the linearizer output
    - R13 – adjusts the slope of the linearizer's output response to the input over all ranges
    - R11 – adjusts the slope of the linearizer's output over the upper end of the input range.
  - Once the initial adjustment is made, prepare for tuning the electrical delay of the RF Input path.

Station RF Controller
Calibration Procedure

- Calibrate the electrical delay of the RF Input path.
  - Return the NWA to a "Lin Freq" sweep with Center 53MHz and a Span of 20 MHz. Set the NWA source power to +7dBm. Ensure that the Phase Offset is returned to 0 deg for this measurement.
  - Disconnect the waveform generator from the "RF Drive Prg." Input and use a fixed DC source set at ***7.0 V*** instead.
  - Perform a NWA calibration
  - Re-install the cable between J3 and J4.
  - Station RF Controller settings:
    - RF Drive Prg. = 7.0 V
    - RFCQG = 9.0 V
    - Limit Level = 8.0 V
    - Loop Gain = 0.0 V
  - Measure the electrical delay between the R.P. "RF Input" and the R.P. RF Out 1.
  - Adjust the "RF Input" tunable cable for a nominal electrical delay of ***16.332 ns*** at 53 MHz.
  - Once the cable has been completed, prepare for the final adjustment of the VGA Linearizer.

- Final calibration of the Linearizer
  - Return the NWA to the state needed for calibrating the Linearizer. Again load in the reference NWA state file and set the NWA as previously at the beginning of this sequence.
  - Disconnect the cable from J3 to J4 and again measure between the R.P. "RF Input" and J3 on the RF Board.
  - Make any necessary adjustments to the Linearizer to match the response as closely as possible to the memory trace.

- Use the available Mathcad files to validate the calibration
  - Store the NWA data to a data file in ASCII format.
  - Store the Linearizer input and output waveforms in "Spreadsheet" format using the Tektronix scope save waveform functions
  - Use Excel to convert the saved files to Tab delimited text files that can be imported into the Mathcad file.
  - Run the Mathcad file and validate the calibration. Compare the results to previous calibrations.

- The intent is to match all units so that for a +7dBm RF Input signal the same signal level appears at J3 for all units at a "RF Drive Prg." Input of 7.0 V. Furthermore, the response should

be as linear as possible over as wide a range as possible with as little error from the ideal response of an s21 linear magnitude of 0.0716 per volt.

- ***Thus at +7dBm RF Input and 7.0 V "RF Drive Prg.", the magnitude of s21 from the R.P. "RF Input" to J3 should be –6.0 dB.***

23.) Confirm all RF Monitors are functioning ☒

23.) Make a final set of RF path and component measurements ☐

New VGA

Station RF Controller Calibration Results Summary

S/N:	005
Date:	7-30-19
Calibrator:	RP

Signal Path	NWA Source Power (dBm)	s21 (dB)	Electrical Delay (ns)	Group Delay (ns)	
J7 -> RF Out 1	-10	3.71	N/A	N/A	
RF FF IN -> RF Out 1 of 8	-10	10.55			Atten = 1dB at J6
Direct RF FB IN -> RF Out 1 of 8 Loop Gain = 3.5 V OLG=9V	-25	9.89			

Matching RF Drive Path and RF Error Path Electrical Delays				
J1 -> J6 (FB Path) RFCQG=9.0 V Drive+Error Limit Level = 8.0 V J3 & J4 terminated in 50Ohm Loop Gain = 3.5 V	-25			
J1 -> J6 (RF Drive Path) RFCQG=9.0 V Drive+Error Limit Level = 8.0 V J3 & J4 cable inserted Loop Gain = 0.0 V	-20			

RF Input Path after VGA Calibration					
RF IN -> J3 RF Drive Prg. = 7.0 V	7	-0.81	~~N/A~~	~~N/A~~	VGA Serial #: 32
RF Input -> RF Out 1 of 8 OLG RFCQG = 9.0 V miter = 8.0 V oop Gain = 0.0 V RF Drive Prg. = 7.0 V	7	-3.12			Attenuators = VGA output 1dB

Front Panel RF Monitors				
OLG RF IN -> RF Output Monitor ~~RFCQG~~ = 9.0 V Drive+Error Limit Level = 8.0 V Loop Gain = 0.0 V Drive Prg=7v	7	-12.71	N/A	N/A
OLG RF IN -> RF Input Monitor ~~RFCQG~~ = 9.0 V Drive+Error Limit Level = 8.0 V Loop Gain = 0.0 V	7	-16.67	N/A	N/A
OLG RF IN -> RF Drive+Error Monitor ~~RFCQG~~ = 9.0 V Drive+Error Limit Level = 8.0 V Loop Gain = 0.0 V	7	-33.20	N/A	N/A
RF Feed Forward IN -> RF Feed Forward Monitor	-10	-19.50	N/A	N/A
Direct RF FB -> Raw RF Error Monitor Loop Gain = 3.5 V	-25	-22.85	N/A	N/A
Direct RF FB -> Amplified RF Error Monitor oop Gain = 3.5 V	-25	-8.91	N/A	N/A

012 VGA

S/N:	005
Date:	7/2/2004

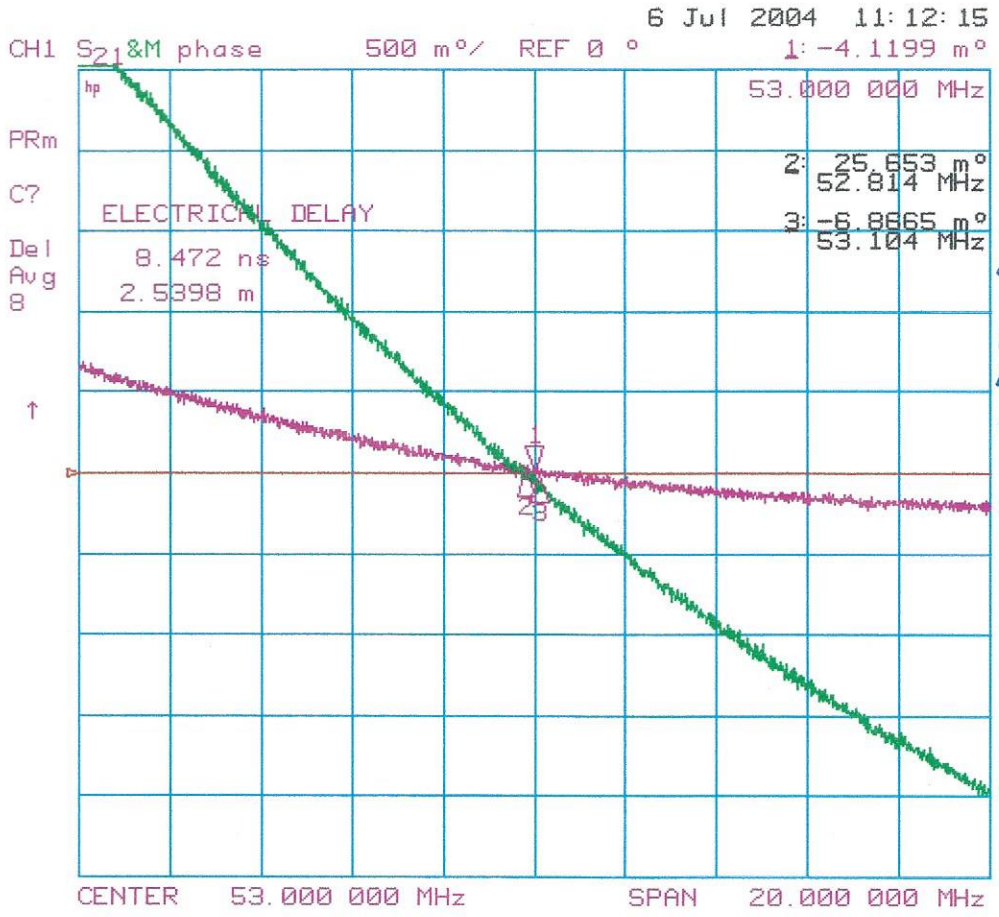
Station RF Controller Calibration Results Summary

Signal Path	NWA Source Power (dBm)	s21 (dB)	Electrical Delay (ns)	Group Delay (ns)	
J7 -> RF Out 1	-10	3.89	N/A	N/A	
RF FF IN -> RF Out 1 of 8	-10	10.67	8.866	8.960	Atten = 1 dB
Direct RF FB IN -> RF Out 1 of 8	-25	9.84	11.833	12.389	

Matching RF Drive Path and RF Error Path Electrical Delays					
J1 -> J6 (FB Path) RFCQG=9.0 V Drive+Error Limit Level = 8.0 V J3 & J4 terminated in 50Ohm Loop Gain = 3.5 V	-25	11.25	8.475	9.128	
J1 -> J6 (RF Drive Path) RFCQG=9.0 V Drive+Error Limit Level = 8.0 V J3 & J4 cable inserted Loop Gain = 0.0 V	-20	-7.43	8.472	8.583	

RF Input Path after VGA Calibration					
RF IN -> J3 RF Drive Prg. = 7.0 V	7	-6.04	N/A	N/A	VGA Serial #: N1113971
RF Input -> RF Out 1 of 8 RFCQG = 9.0 V Limiter = 8.0 V Loop Gain = 0.0 V RF Drive Prg. = 7.0 V	7	-6.75	16.327	16.216	Attenuators = 20+3+2

Front Panel RF Monitors				
RF IN -> RF Output Monitor RFCQG = 9.0 V Drive+Error Limit Level = 8.0 V Loop Gain = 0.0 V	7	-16.4	N/A	N/A
RF IN -> RF Input Monitor RFCQG = 9.0 V Drive+Error Limit Level = 8.0 V Loop Gain = 0.0 V	7	-21.98	N/A	N/A
RF IN -> RF Drive+Error Monitor RFCQG = 9.0 V Drive+Error Limit Level = 8.0 V Loop Gain = 0.0 V	7	-37.0	N/A	N/A
RF Feed Forward IN -> RF Feed Forward Monitor	-10	-19.4	N/A	N/A
Direct RF FB -> Raw RF Error Monitor Loop Gain = 3.5 V	-25	-22.8	N/A	N/A
Direct RF FB -> Amplified RF Error Monitor Loop Gain = 3.5 V	-25	-8.88	N/A	N/A



Station RF Controller
S/N 005
w/ Thru Resp. Cal.
+N-f → SMA-f
and N-m → SMA-m

RFCQG = 9.0v
Limiter = 8.0v
IF Bw = 3 kHz 1601pts

← J1 cable → J6
RF Drive Path
FB Gain = 0.0v

← J1 → J6 (FB Path)
w/ J3 + J4 terminated
Loop Gain = 3.5 v