



Procedure Title *1497 MHz Vertical Testing Procedure*

Procedure ID # *CP-C100-CAV-VTRF*

Procedure Description - The procedure address the current instructions for testing 7-cell C100 style cavities for the 12 GeV upgrade project. All exceptions to the procedure must be noted in a D3 for the current test. The procedure consists seven parts: Related Documentation, Initial Tasks, Cavity Passband Measurements, Key HOM frequencies and Q_L measurements Using Network Analyzer, Cable Calibrations, High Power RF Test of the Cavity and How to fill out the cavity performance traveler.

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References	List and Hyperlink all documents related to this procedure.		
	VTA SOP		
	C100-CAV-VTRF		
	Excel spreadsheet template for VTA RF measurements.		
	CP-C100-CAV-VTRF-HOM.		
	CP-C100-CAV-VTRF-HOM-POLFIT		
	Excel spreadsheet template for VTA HOM measurements.		
	Excel macro for VTA HOM measurements		
	Excel file for CEBAF_7_cell_PassBandModeAnalysis.xlsx		
	HOM Acceptance Criteria V1.0-1 with Freq.xlsx		
	Theory and practice of cavity RF test systems.		
	An automated RF data acquisition system for testing RF s.c. cavities.		

1497 MHz Vertical test procedure

The procedure consists of seven parts: Related Documentation, Initial Tasks, Cavity Passband Measurements, Key HOM frequencies and Q_L measurements Using Network Analyzer, Cable Calibrations and High Power RF Test of the Cavity

I. Related Documentation

1. Required training: Radiation Worker I.
2. Read the VTA Standard Operating Procedure.
3. Read and sign the Radiation Work Permit.
4. T. Powers: Theory and practice of cavity RF test systems
5. C. Reece, T. Powers and P. Kushnick: An automated RF control data acquisition system for testing superconducting RF cavities”.
6. F. Marhauser: HOM test procedure

**IF AT ANY TIME THE RF TEST GOES BEYOND THE SCOPE OF THIS DOCUMENT
CONTACT THE VTA FACILITY MANAGER FOR GUIDENCE.**

II. Initial tasks

- Use approved RF components: Network analyzer, reference power meter and power meter sensor, RF cables, connectors, circulator, RF loads. Launch D3 if not.
- Contact cryogenic support to establish how much Helium level is required to cover the cavity (C100 7-cell cavities require a minimum of approximately 140 cm).
- If cavity vacuum is above 1E-5 mBar, abort high power RF test

A. Record the following information in the logbook:

1. Operator name and date
2. Dewar number and top plate id number (found etched in the metal on top plate or as a sticker on the top plate)
3. Note if cavity has Helium vessel or if cavity is mechanically constrained such as with a mechanical tuner.
4. Number of HOM probes to be tested.
5. Cavity vacuum pressure measured at Dewar in mBar (if above 1E-5 mBar, do not test).
6. Helium pressure in Torr (at Dewar cryogenic control system read DEWAR BARATRON PRESSURE Torr indicator).
7. Helium liquid level in centimeters (see Dewar LabVIEW screen of cryogenic control system).
8. Network analyzer and reference power meter used for VTA cavity tests.

B. Setup the HOM Power Meter and Power Meter Sensors as shown in Figure B below. **If no HOM couplers are being used, verify that loads are terminating the HOMs connectors on the top plate.**

1. Remove the HOM power meter and power meter sensors from the storage box on the calibration cart.
2. Plug the HOM power meter into a power outlet located on the dewar shield wall.
3. Connect the HOM power meter to a network cable located on the dewar shield wall.
4. Verify that the power meter sensors also have 20dB attenuators attached.
5. Verify that the HOM power meter is communicating with the LabVIEW software. On the 1497MHz RF Testing computer,
 - i. Launch the National Instruments Measurement and Automation Explorer.
 - ii. Check My System→ Devices and Interfaces→VISA TCP/IP Resources→HOMPowerMeter
 - iii. Click Validate
 - iv. A popup message “Successfully opened VISA session...” should appear. If not, check the network cable connections and power-cycle the HOM power meter.
 - v. Exit the National Instruments Measurement and Automation Explorer program.

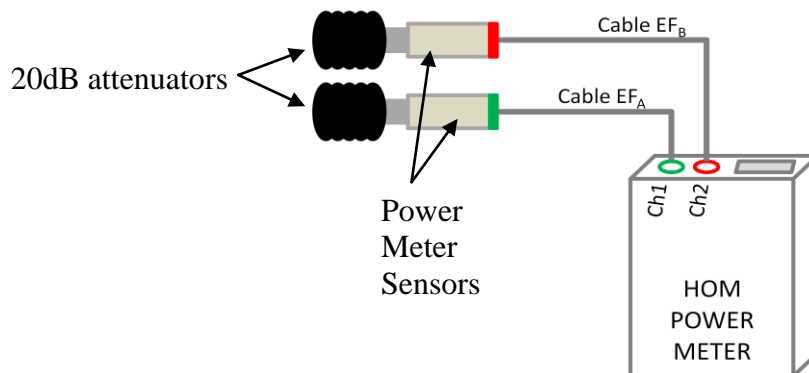


Figure B: HOM Power Meter with Power Meter Sensors and 20dB Attenuators

C. Setup the Dewar Patch Panel as shown in Figure C below.

1. Connect a circulator to the P_{inc} connector on the Dewar Patch Panel
2. Connect a load to the side connector of the circulator
3. Connect a directional coupler to the circulator
4. P_{inc} cable connected to top of directional coupler
5. Bottom connector of directional coupler (Reflected) attached to Dewar Patch Panel “D”
6. Top connector of directional coupler (Incident) attached to Dewar Patch Panel “C”
7. Connect P_{trans} cable to the Dewar Patch Panel P_{trans}

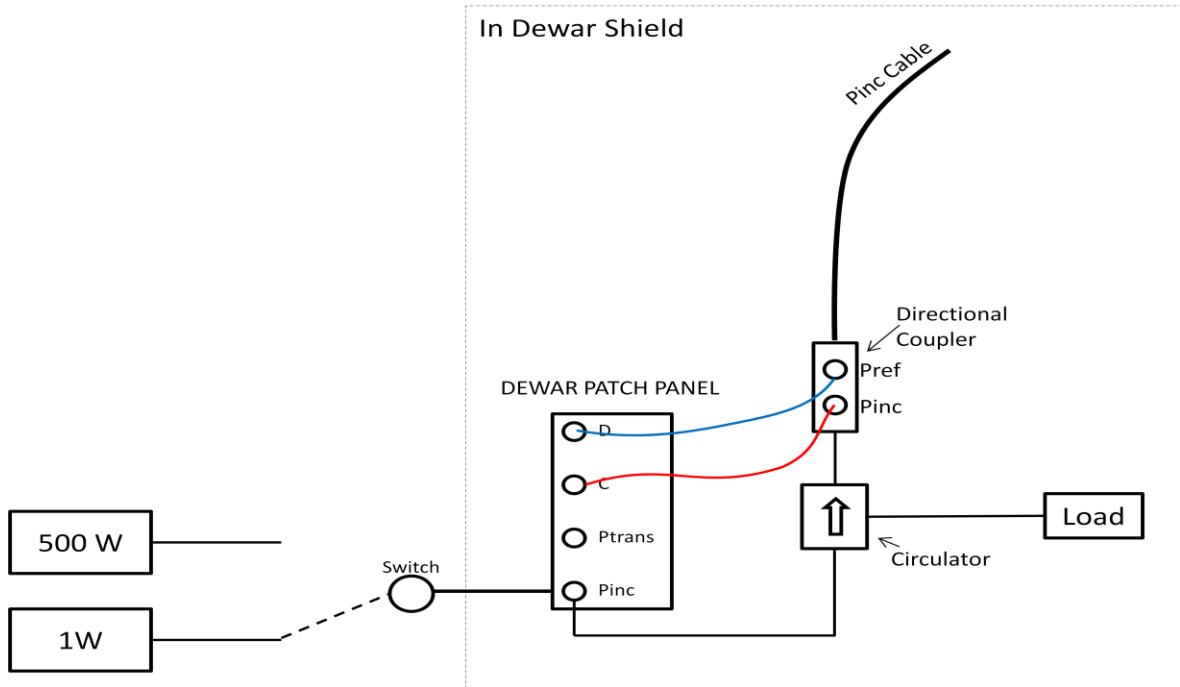


Figure C: Dewar Patch Panel Setup

D. Setup the RF Patch Panel for the Dewar in use

1. Locate the RF Patch Panel on the wall in the VTA Control Room between the cryogenic controls for dewars 4 and 6. See Figure D.
2. Connect the cables from the 1497 MHz System “C” and “D” connectors to the appropriate dewar “C” and “D” connectors. For example: if the cavity to be tested is in dewar 4: connect 1497 MHz System “C” to Dewar 4 “C” and 1497 MHz System “D” to Dewar 4 “D”.

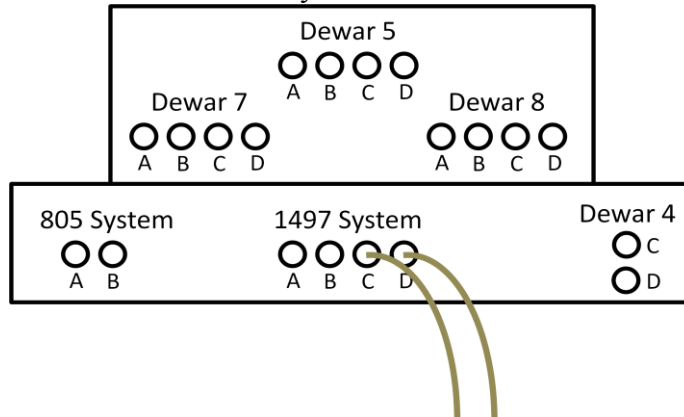


Figure D: RF Patch Panel Setup

- E. Verify the 1497 MHz System setup near the testing computer in the VTA control room.
1. Above the 1497 MHz testing computer, verify that the cable from “D” is connected to P_{ref} on the Power Measurement Network. See Figure E below.
 2. Verify that the cable from “C” is connected to P_{inc} on the Power Measurement Network

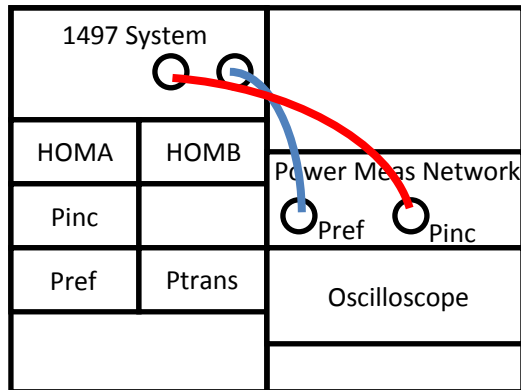


Figure E. 1497 MHz Measurement System Connections

III. Cavity Passband Measurements Using Network Analyzer

Perform these measurements only if Dewar LHe level is above the cavity end group and Dewar temperature is 2.07K. Note these instructions are specific to the Agilent ENA 5071C Network Analyzer. If a different network analyzer is used, the configuration menus may be different.

1. Warm-up the reference power meter and network analyzer for at least 15 minutes before using. Ensure that the network analyzer has valid calibration certificate.
2. Setup the network analyzer by recalling state *VTA 1497*. If unable to recall state:
 - a. Using the Agilent ENA 5071C Network Analyzer (4-port)
 - i. Set Measure to S21
 - ii. On the Scale Menu, set: Divisions = 10, Scale/Div = 20.00 dB/div, Reference Position = 5 Div, Reference Value = +40 dB
 - iii. On the Avg Menu, set: Averaging = OFF, Smoothing = OFF; IF Bandwidth = 1kHz
 - b. Using the Hewlett Packard 8753E Network Analyzer (2-port)
 - i. On MEAS menu, set Measure to S21
 - ii. On AVG menu, set Averaging to OFF, IFBW to 100Hz
 - iii. On MENU, set POWER to 15dBm, POWER to ON, Num of Points to 1601
3. Connect the following cables as shown in Figure III:
 - a. cable GH to port 1 of the Network Analyzer and FPC on Dewar lid top plate.
 - b. cable JK to port 2 of the Network Analyzer and FP on Dewar lid top plate.

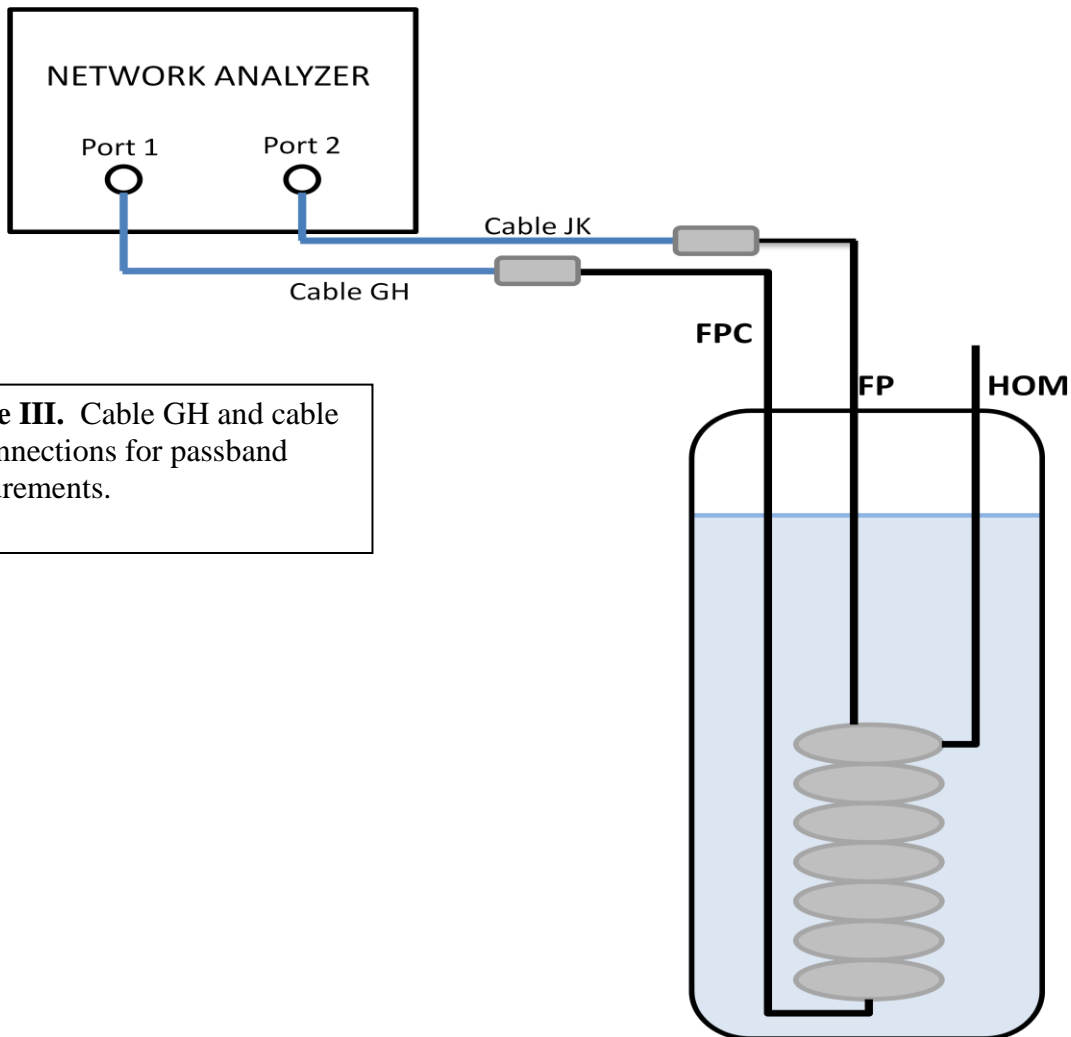


Figure III. Cable GH and cable JK connections for passband measurements.

4. Set **CENTER** to pi mode (approx. 1496.6MHz for C100 cavities)
Set **SPAN** to 1 MHz.
5. Press **MKR FCTN** button.
Select **MKR SEARCH**.
Set **TRACKING ON** and set to **MAX**.
6. Once peak frequency is detected, press **MKR FUNCT** → **CENTER** button.
7. Press **SPAN** button. Enter **50 kHz**.
8. Press **MKR** button to display the measured peak frequency.
9. Write the cavity peak frequency in the logbook.
10. Refer to previous logbook entries of similar cavity passband measurements to aid in finding the remaining passbands. Repeat steps 2 through 8 for all modes in this band.

For lower modes (lower frequencies) use smaller **SPAN** range and increment/decrement the **CENTER** frequency to search for the modes.

Example of passband frequencies for a 7-cell Low Loss type cavity:

7/7 Pi = 1496.7075 MHz
6/7 Pi = 1495.4688 MHz
5/7 Pi = 1492.0414 MHz
4/7 Pi = 1487.1299 MHz
3/7 Pi = 1481.7767 MHz
2/7 Pi = 1476.9200 MHz
1/7 Pi = 1473.6405 MHz

IV. Key HOM frequencies and Q_L measurements Using Network Analyzer

At 2.07K measure key HOM frequencies and Q_L per [CP-C100-CAV-VTRF-HOM Measurements procedure](#) and CP-C100-CAV-VTRF-HOM-POLFIT procedure. Record the name of the HOM surveyor, date, time, and HOM data file name. In summary, save in the Excel spreadsheet template for VTA HOM measurements the HOM spectra for modes TE111, TM110 and TM111 identified with a Network analyzer, use the enhanced Polfit Mathematica package to extract the frequencies and Q_{loaded} values and then, the Excel macro for VTA HOM measurements to generate the HOM processed data excel file.

V. Cable Calibrations

1. Once all these modes have been located, calculate the CW frequency and record in the logbook:
CW freq = P_i mode frequency + 50 kHz
2. Setup the Reference Power Meter and Network Analyzer for CW measurements.
 - a. Warm-up the reference power meter and network analyzer for at least 15 minutes before using. Ensure that the network analyzer has valid calibration certificate.
 - b. Verify that the reference power meter frequency is set to 1497 MHz. Zero and calibrate the power meter sensor as specified in the power meter manual. Ensure that the power meter and power meter head have valid calibration certificate.
 - c. If using the Agilent ENA 5071C Network Analyzer (4-port), recall state *VTA1497 CW Meas.* **To avoid damaging the Network Analyzer, operate in CW mode only while performing the cable calibrations.** If unable to recall state:
 - i. Turn off the initial source port control function: System→Service Menu→Init Src Ctrl[Off]
 - ii. Press Sweep Setup→Power→RF Out [ON, 10dB]
 - iii. Press Sweep Setup→Power→Port Couple [OFF]
 - iv. Sweep Setup→Power→CW Freq, enter the CW frequency calculated in Step 1.
 - v. Span, enter 0Hz.
 - d. If using the Hewlett Packard 8753E Network Analyzer (2-port), recall state *VTA1497*. If unable to recall state:
 - i. On MEAS menu, set Measure to S21
 - ii. On AVG menu, set Averaging to OFF and IFBW to 100Hz
 - iii. On MENU, set POWER to 15dBm, POWER to ON, Num of Points to 1601
 - iv. On MENU, press CW FREQ and enter the CW frequency calculated in Step 1.
3. In the VTA control room, set Dewar selection switch to Dewar that contains the cavity under test.
NOTE: Once the software is running, changing the switch will cause a software error which stops the VI.
4. Verify the:
 - a. 3-way switch labeled 0 OPEN 180 is in OPEN position to open the PLL feedback loop.
 - b. TRANSMITTED POWER NETWORK switch is in the up position (LED is ON).
 - c. RF/INTERRUPT switch is on INTERRUPT
 - d. RF ENABLE ON/OFF switch is OFF.
 - e. AMP POWER SELECT HI or LO is set to LO.
5. Run the LabVIEW program named **VTA_main.vi** If VTA_main.vi does not run, contact Christiana Grenoble at 5850 or Kirk Davis at 6086 (cell phone numbers can be found on the VTA Status whiteboard).

6. A window will appear as shown in figure Va, and cavity information should be provided:
 - Select the cavity type from the dropdown menu at point 1 to have $\sqrt{R/Q}/L=42.11$
 - The cavity serial number can be determined from the white board in the VTA control room. The data file name will be determined by the cavity serial number. If more than one test has been conducted, the data file name will be the cavity serial number with an uppercase letter appended to the end of it.
 - If HOM couplers are used, select HOM A & B.
 - If no HOM couplers are used, select No HOMs.
 - When all the information is filled in, press the CLOSE button to continue to the main RF testing screen.

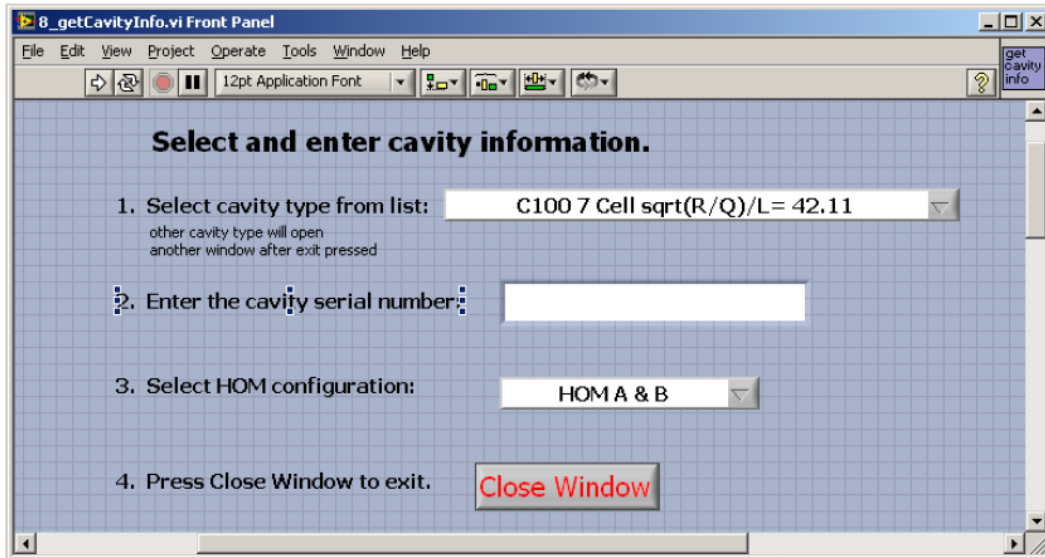


Figure Va. LabVIEW VTA_Main.vi startup screen.

7. Zero the power meters by clicking the red button labeled Zero Power Meters.
8. Run the cable calibration program by clicking the red button labeled Calibrate Cables. A window will appear as shown in Figure Vb:

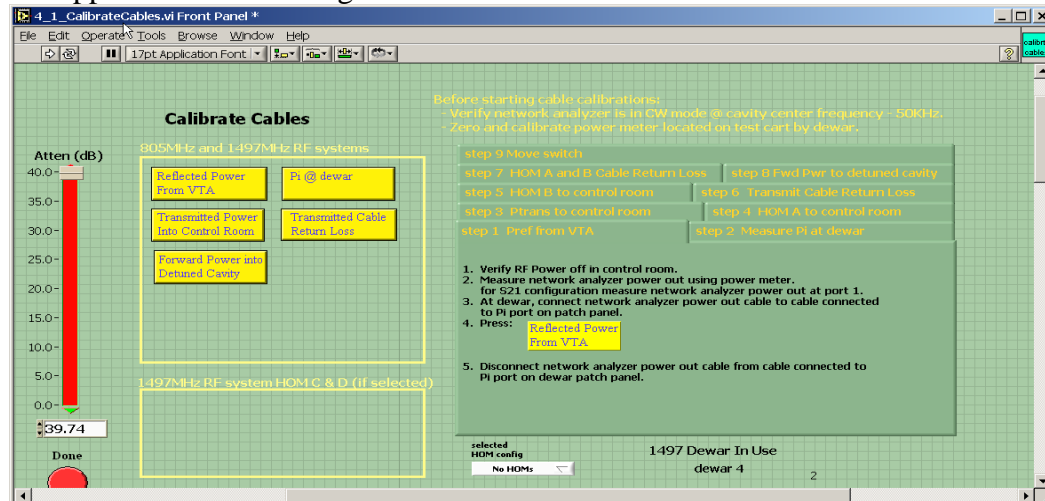


Figure Vb. The cable calibration VI displays instructions to conduct the cable calibration in a tabbed format. Each tab is a numbered step

9. Check the attenuator slide is at 40 dB and AMP switch to LO.
10. Block diagram representations of the following steps are provided in Section VIII: Supplemental.

A. Power into Control Room Measurements

1. Power Out from Network Analyzer

- Verify RF Power off in control room.
- At Dewar, connect cable GH from the network analyzer to the reference power meter sensor.
- Measure network analyzer power out (for S21 configuration measure network analyzer power out at port 1 and CW freq) using the reference power meter.
- Write down in the logbook the measured network analyzer power out read on the reference power meter. This value will be used as the network analyzer power output for Steps 2, 3, and 4.

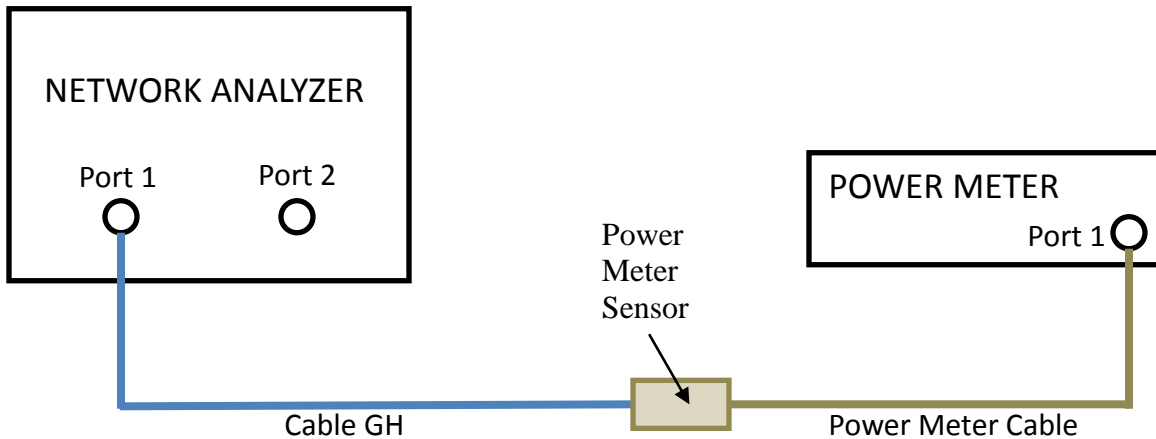


Figure 1. Network Analyzer connection to Reference Power Meter

2. Reflected Power from VTA

- At Dewar, connect cable GH from network analyzer to cable AB (P_{INC}) as shown in Figure 2.
- In cable calibration VI, click button labeled 'Reflected Power From VTA'.
- A pop-up will appear, and enter the network analyzer power out (from Step 1d) in the yellow highlighted field.
- Click **Done** button when finished.
- Disconnect cable GH from cable AB.

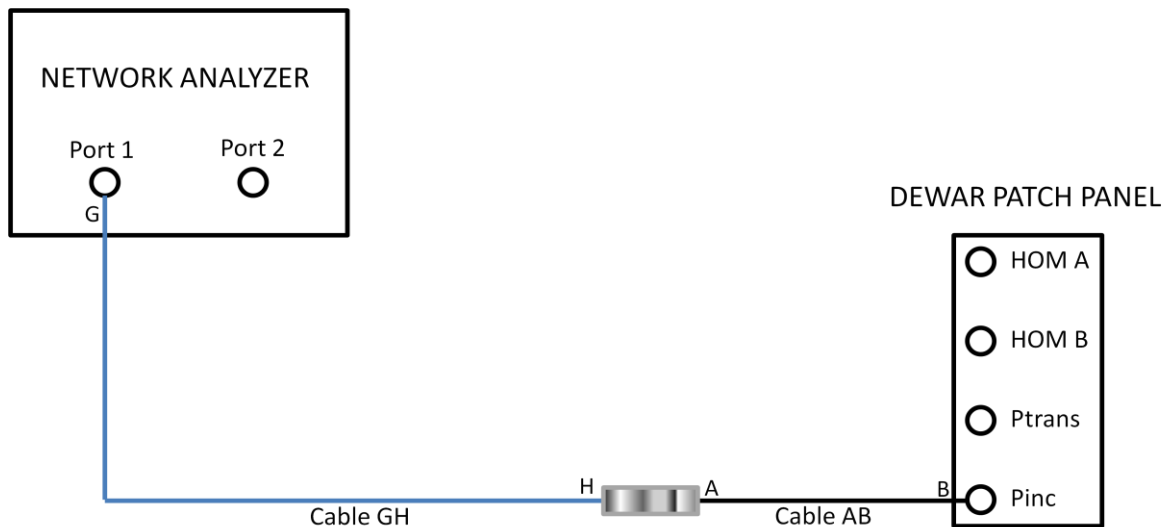


Figure 2. Network Analyzer connection to P_{INC}

3. **Transmitted Power Into Control Room**

- a. At Dewar, connect cable GH from network analyzer to cable CD (P_{TRANS}) as shown in Figure 3.
- b. In cable calibration VI, click button labeled 'Transmitted Power Into Control Room'.
- c. A pop-up will appear, and then enter the network analyzer power out (from Step 1d) in the yellow highlighted field.
- d. Click **Done** button when finished.
- e. Disconnect cable GH from cable CD.

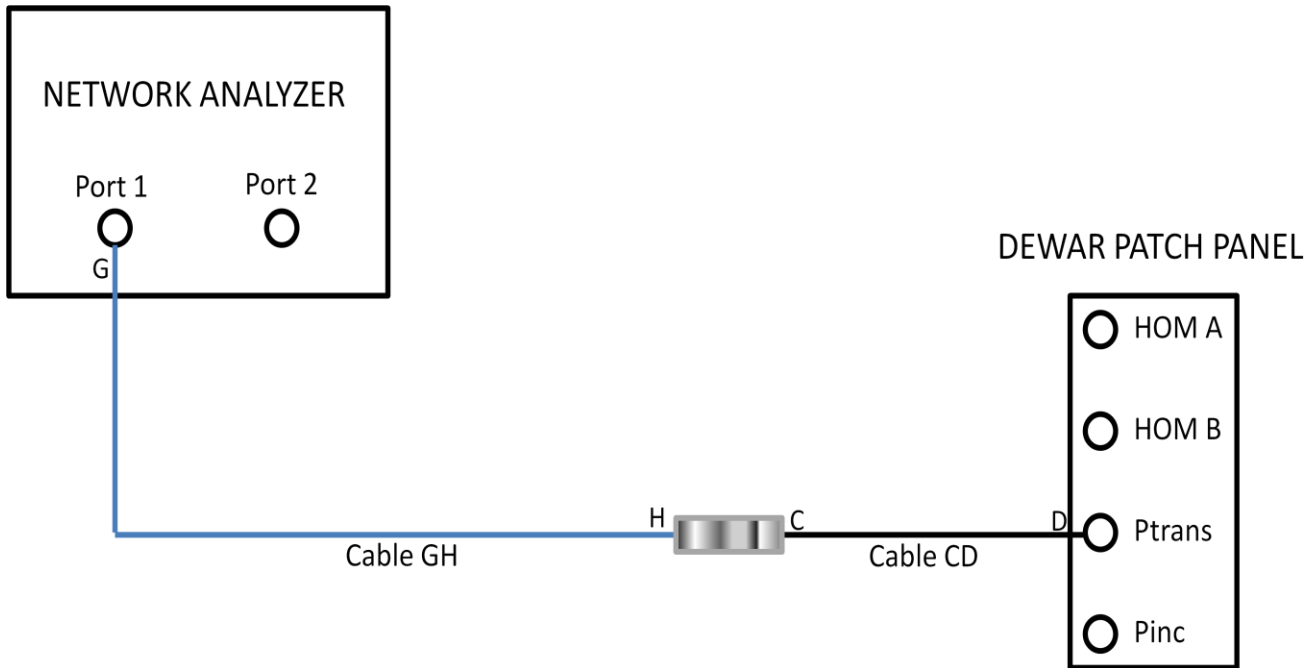


Figure 3. Network Analyzer connection to P_{TRANS}

4. HOMA Power Into Control Room

- At Dewar, connect cable GH from network analyzer to cable EF_A (PM_{HOMA}) as shown in Figure 4.
- In cable calibration VI, click button labeled 'HOMA Into Control Room'.
- A pop-up will appear, and then enter the network analyzer power out (from Step 1d) in the yellow highlighted field.
- Click **Done** button when finished.
- Disconnect cable GH from cable EF_A.

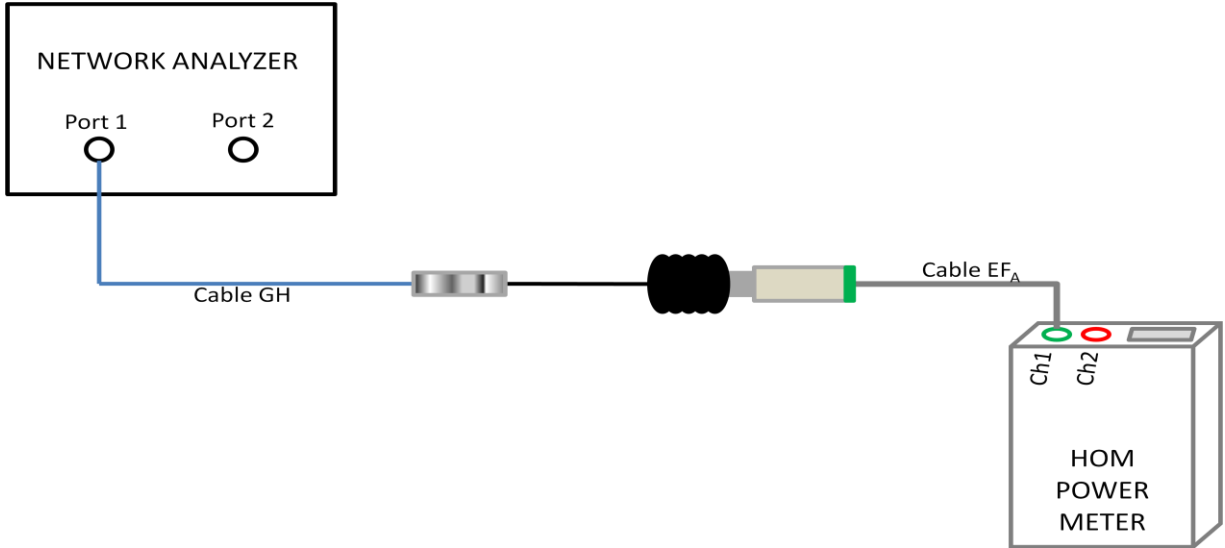


Figure 4. Network Analyzer connection to PM_{HOMA}

5. HOMB Power Into Control Room

- At Dewar, connect cable GH from network analyzer to cable EF_B (PM_{HOMB}) as shown in Figure 5.
- In cable calibration VI, click button labeled 'HOMB Into Control Room'.
- A pop-up will appear, and then enter the network analyzer power out (from Step 1d) in the yellow highlighted field.
- Click **Done** button when finished.
- Disconnect cable GH from cable EF_B.

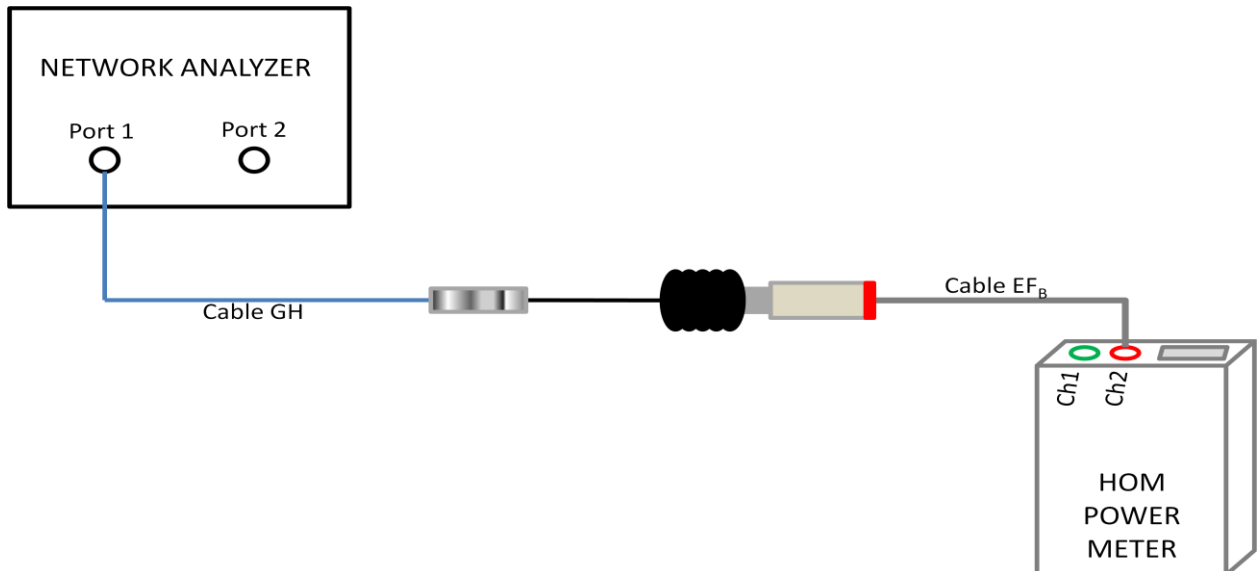


Figure 5. Network Analyzer connection to PM_{HOMB}

B. Incident Power at Dewar

1. In *Calibrate Cables VI* check that the attenuator is at 40 dB.
2. Connect cable AB (P_{INC}) to the power meter as shown in Figure B.
3. In *Cable calibration VI*, set attenuation to 20dB.
4. Turn low power RF on in control room by setting the RF ENABLE switch to the ON position and the RF/Interrupt switch to RF.
5. Set frequency = Pi mode frequency +50 kHz using coarse/fine frequency knobs on transmit phase detector module.
6. At Dewar, verify that the reference power meter frequency is set to 1497 MHz. Record the Power Meter value in the logbook.
7. In *Cable Calibration VI*, click button labeled 'Pi @ Dewar'.
8. A pop-up screen will appear, enter the incident power measured at the Dewar from Step B6.
9. Click **Done** button when finished.
10. Turn RF Power OFF in control room by setting the RF ENABLE switch to the OFF position.

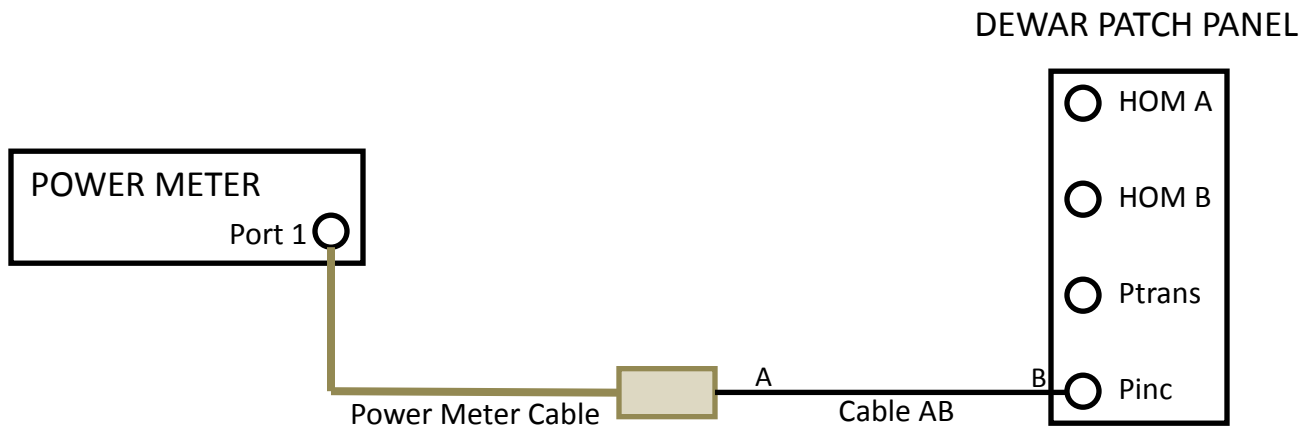


Figure B. Reference Power Meter connection to P_{INC}

C. Cold Cable Return Losses

1. Calibrated Open Measurement

- Connect circulator ports 1, 2, and 3 as shown in Figure C1:
 - Port 1 - Cable GH
 - Port 2 - Calibrated Open
 - Port 3 - Power meter sensor.
- With cable GH and attachments extended close to the Dewar top plate near P_{TRANS} , P_{INC} , P_{HOMA} , and P_{HOMB} feedthroughs, record the power meter reading in the logbook. Use this reading as the P_{OPEN} value for the 'Transmitted Cable Return Loss' and 'HOMa and HOMb Cable Return Loss' measurements.

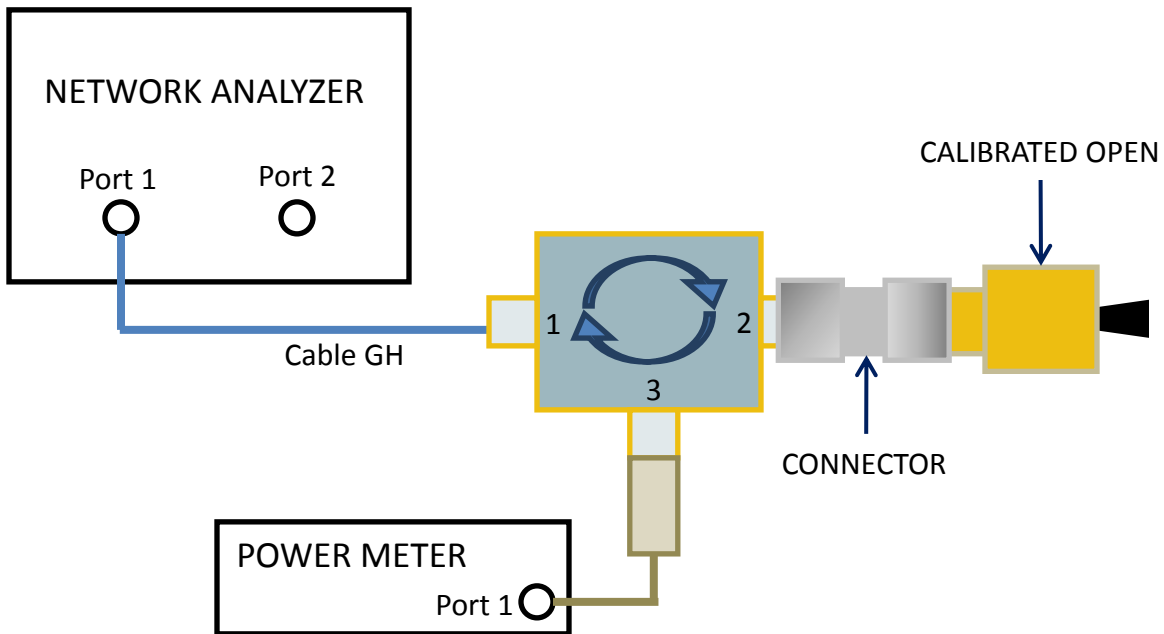


Figure C1. Circulator connected to Network Analyzer, Calibrated Open, and Power Meter

2. Transmitted Cable Return Loss

- a. At Dewar, connect circulator ports 1, 2, and 3 as shown in Figure C2:
 - Port 1 - Cable GH
 - Port 2 - Cavity Field Probe (FP) connector on top plate
 - Port 3 - Power meter sensor.
- b. Write down the measured power in the logbook.
- c. In *Cable Calibration VI*, click button labeled 'Transmitted Cable Return Loss'.
- d. A pop-up screen will appear, enter P_{OPEN} (Step C1) and field probe power (Step C2b) measurements. Click **Done** when finished.

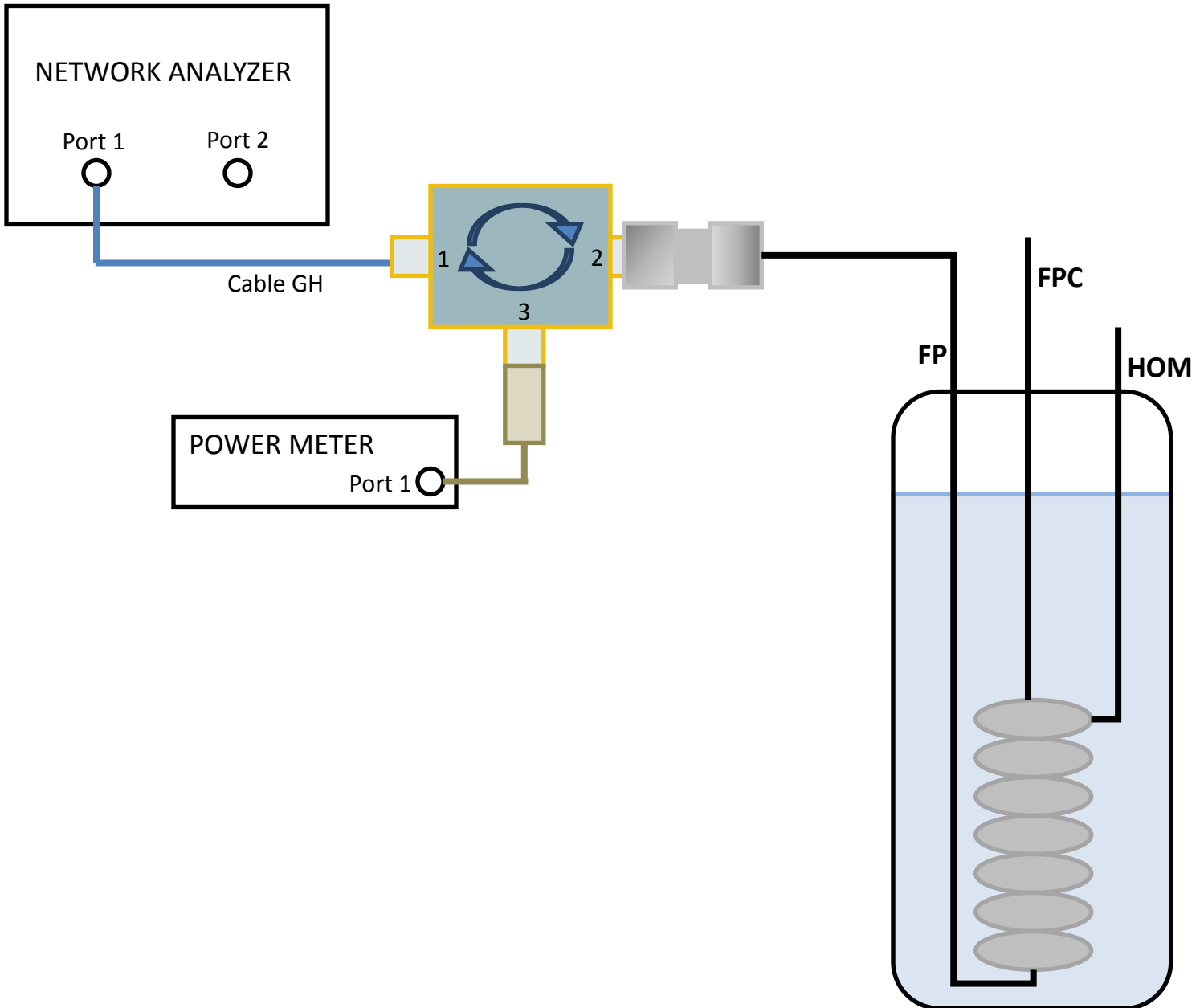


Figure C2. Circulator connected to Network Analyzer, FP Cable, and Reference Power Meter

3. HOMA Cable Return Loss

HOM ports are sometimes labeled on the Dewar lid: top HOM [HOMA] and bottom HOM [HOMB]

- a. At Dewar, connect circulator ports 1, 2, and 3 as shown in Figure C3:
 - Port 1 - Cable GH
 - Port 2 - HOMA connector on top plate
 - Port 3 - Reference Power meter sensor.
- b. Write down the measured power in the logbook.
- c. In *Cable Calibration VI*, click button labeled 'HOMA Cable Return Loss'.
- d. A pop-up screen will appear, enter P_{OPEN} (Step C1) and HOMA (Step C3b) measurements. Click **Done** when finished.

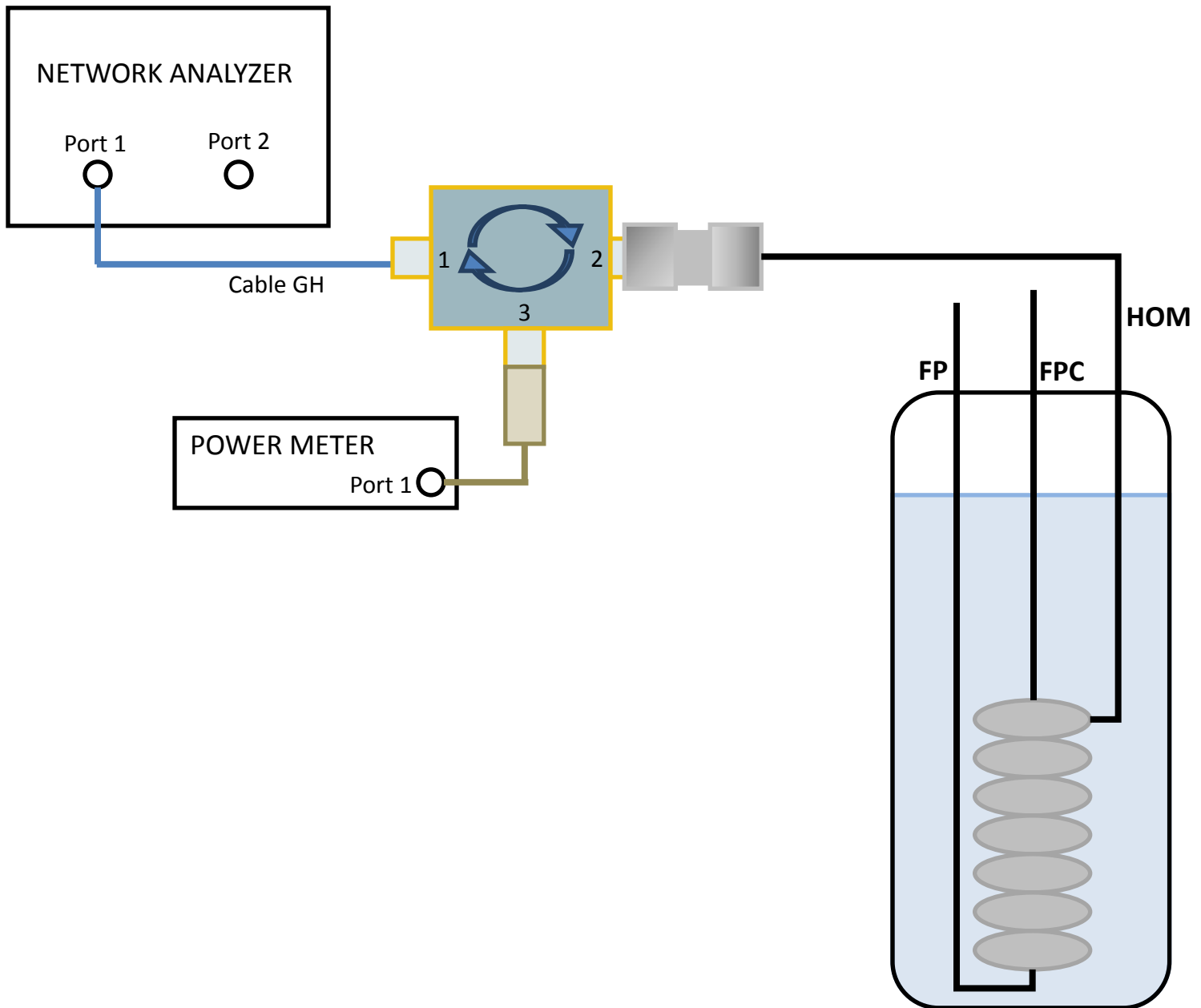


Figure C3. Circulator connected to Network Analyzer, HOM Cable, and Power Meter

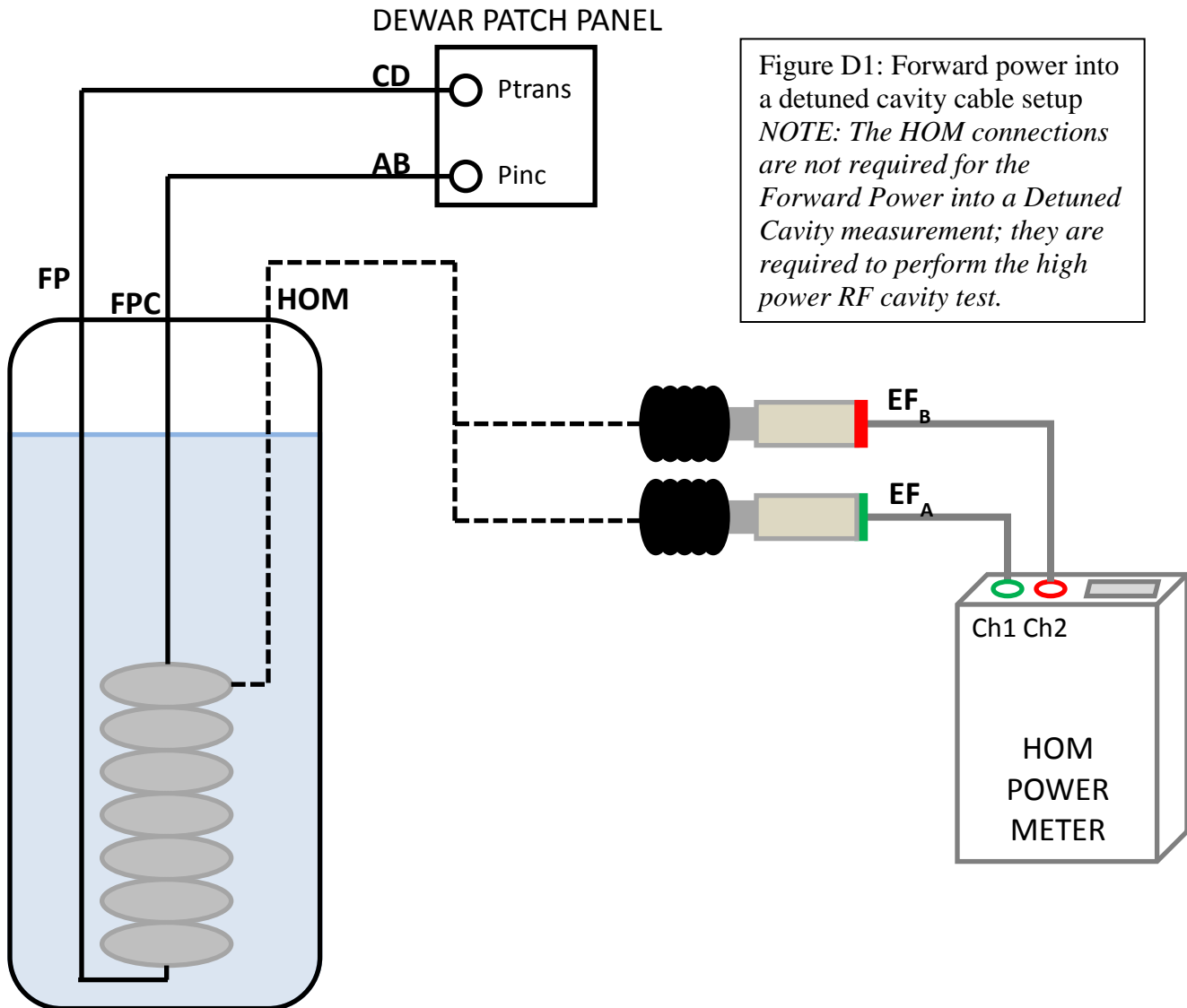
4. HOMB Cable Return Loss

HOM ports are sometimes labeled on the Dewar lid: top HOM [HOMA] and bottom HOM [HOMB]

- a. At Dewar, connect circulator ports 1, 2, and 3 as shown in Figure C3 above:
 - Port 1 - Cable GH
 - Port 2 - HOMB connector on top plate
 - Port 3 - Power meter sensor.
- b. Write down the measured power in the logbook.
- c. In *Cable Calibration VI*, click button labeled 'HOMB Cable Return Loss'.
- d. A pop-up screen will appear, enter P_{OPEN} (Step C1) and HOMB (Step C4b) measurements. Click **Done** when finished.

D. Forward Power Into a Detuned Cavity

1. Connect all cables from Dewar Patch Panel to the connectors on the top plate as shown in Figure D1:
 - cable AB to Fundamental Power Coupler [FPC] port
 - cable CD to Field Probe [FP] port
 - HOMA power meter sensor/attenuator to the HOMA port
 - HOMB power meter sensor/attenuator to the HOMB port



2. Clear area and close Dewar lid.
3. In control room, move 3-way switch labeled '0 OPEN 180' to OPEN to open the PLL feedback loop.
4. Turn low power RF ON by switching RF ENABLE to ON and RF/INTERRUPT to RF. In *Cable Calibration VI*, set Atten to 20 dB using slide control.
5. Adjust frequency to be OFF resonance (use the CW frequency value as specified at Step V1).
6. Verify Pt power meter reads ~ 0W.
7. In *Cable Calibration VI*, click button labeled 'Forward Power into Detuned Cavity'.
8. A pop-up screen will appear and quickly disappear without any operator interaction.
9. Turn RF ENABLE switch to the OFF position.

10. Upon completing the cable calibration, click the button labeled **Done** in the *Cable Calibration VI*.
11. A window will open to display the difference between the current calibration and the last calibration performed in the Dewar. Any differences between current and last cable calibration should be understood before continuing. $\text{Percent difference} = ((10^{(\text{dB difference}/10)} - 1) * 100)$
12. Click on the button labeled **Done** to exit the calibration comparison window.
13. A window will appear requesting the operator to replace or cancel overwriting the cable calibration file. Partial calibration values can be written to the file if an obvious error in new cable calibration exists. Select cancel to skip writing the new calibration data to the calibration file. Select replace to write the new cable calibration data to the calibration file.
14. The main LabView VI screen will be displayed when the calibration is finished.
15. To verify the cable calibration: turn RF Enable to ON, verify Power to LOW, and set the attenuation to 0dB. From the 'Live Numbers' tab, the forward power (P_{inc}) and reflected power (P_{ref}) should both read about 0.5 W. Return the attenuation to 40dB before continuing.
16. If using the Agilent ENA 5071C Network Analyzer (4-port), return the Network Analyzer to its default initial source port control setting:
System->Service Menu->Init Src Ctrl[ON]

VI. High Power RF tests of Cavity

1. Preparations for High Power Cavity Testing

- a. Verify Dewar shield is closed.
- b. Notify personnel working in test area that a high power RF test is about to begin. Verify they are wearing their TLD's and they have signed the VTA RWP.
- c. Close the VTA fence and flip up all Radiological Posting signs per instructions in the VTA SOP.
- d. In the VTA Operational Safety Log Book enter: date, cavity name, operator name and Dewar number.
- e. At the PSS system panel, move the key from disable to enable position and press Reset button.
- f. In the software, set the Attn slide switch to 40 dB.
- g. Turn on high power amplifier located in test area.
- h. Turn high power RF ON by: verifying AMP switch is in the up position (LED on), setting the Amp Power mechanical switch from LOW to HIGH and setting the RF ENABLE switch to ON.
- i. Verify the cavity is not locked, by check transmitted power meter is reading ~0 W.
- j. In the logbook, record the dewar pressure and liquid level.

2. Dissipated Power Measurement (may be repeated at anytime)

- a. In software, set $Q_{ext2} = 1000$. (There are two modes for measuring Q_{ext2} : CW mode is selected whenever the value entered for $Q_{ext2} > 100$; decay mode is selected whenever the value entered for $Q_{ext2} \leq 100$)
- b. Verify the 3-way switch labeled '0 OPEN 180' is in the OPEN position to open the PLL feedback loop.
- c. Set the attenuation slider control such that the cavity incident power level is between 1-3W. For C100 7-cell cavities, use 23.4dB. Record the attenuation setting used in the logbook; this value will be referred to as the Reference Attenuation Setting throughout this procedure.
- d. After the P_{loss} reading stabilizes, click 'Measure and Log' button in the software.
- e. Verify the P_{loss}/P_{inc} ratio is less than 0.003. If it is not, repeat the Forward Power into Detuned Cavity Step in the cable calibration routine using the Reference Attenuation Setting. Repeat the Dissipated Power Measurement. If the ratio is not less than 0.003, turn high power OFF. Check that cable connections at the Dewar are tight and repeat steps b – e.
- f. Note that changing cables or tightening connectors may require at least a partial cable calibration.
- g. Once P_{loss}/P_{inc} ratio is less than 0.003, the dissipated power measurement is complete.
- h. Write down the power meter correction factors from the **VTA_main.vi** screen in Default view 'Last Logged Point' tab. They are displayed in the *PM corr fac* cluster as C_i , C_r , C_t , C_{HOMA} and C_{HOMB} .

3. Initial Cavity Tuning

- a. Verify that the attenuation is set to the Reference Attenuation Setting used above in Step 2c.
- b. Move the 3-way switch labeled '0 OPEN 180' to the 0 position to close the PLL feedback loop.
- c. Verify that high power RF is ON.
- d. In the software, switch to the 'Live Numbers' read back tab. The software will report the most current power levels.
- e. Using the fine frequency knob on the PLL chassis, tune the cavity to the cavity lock frequency by adjusting frequency and then the phase knob until transmitted power is at maximum level. Record the cavity lock frequency in the logbook.

4. Measure Cavity Coupling

- In software, set $Q_{ext2} = 1000$. (CW mode : $Q_{ext2} > 100$ Decay mode: $Q_{ext2} \leq 100$)
- On the scope, decrease the volts/division for the reflected power signal until the trace reads above zero. Set the horizontal time scale for 2 seconds.
- Set attenuator slide control to the Reference Attenuation Setting (see Step 2c) and tune the cavity phase to maximize transmitted power.
- Click the software control 'SET MIXER LEVEL' and retune the phase as required.
- Select the 'Pulse Mode' tab in software and turn **ON** pulse mode. If the cavity does not relock after the Pulse Mode turns RF power back on, relock the cavity manually by adjusting the fine frequency knob on the PLL chassis. Do not continue with this measurement until the cavity consistently relocks independently once RF power is pulsed on.
- When the scope displays a decay shape on reflected power, press the **Stop/Run** button on the scope to stop scrolling and freeze the screen.
- Open TDS420getData_tp2.vi to capture the scope screen and save the decay file.
- Input in CavID in the **File Name prefix** on the TDS screen (See Figure 8). Insert in the **Comment field** the CavID, test date and cavity coupling

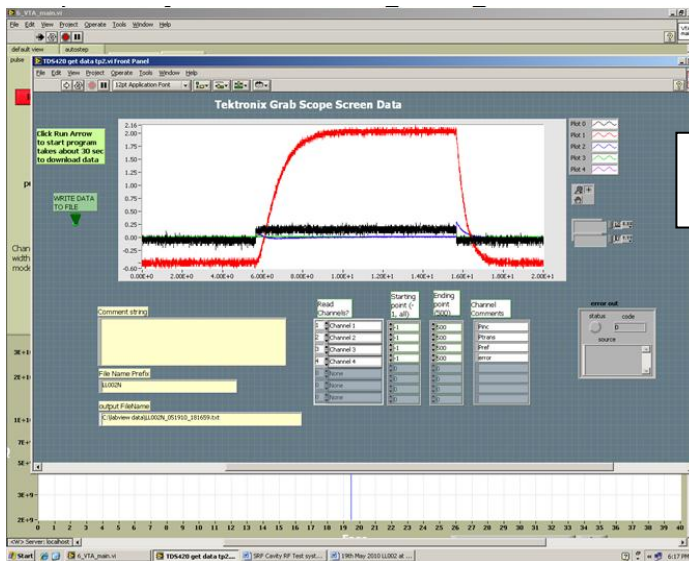


Figure 8 Examples of oscilloscope traces as recorded by the TDS420getData_tp2.vi.

- Run TDS420getData_tp2.vi to capture the oscilloscope screen in the text file.
- Write in the logbook the name of the TDS text file displayed in the Output file name.
- The shape of the reflected power signal during the decay indicates the cavity coupling. An example of the over coupled, under coupled and critically coupled cavity pulse shape can be found below, in Figure 9. Note the relative amplitude of reflected power peaks when RF power ON vs. RF power OFF.

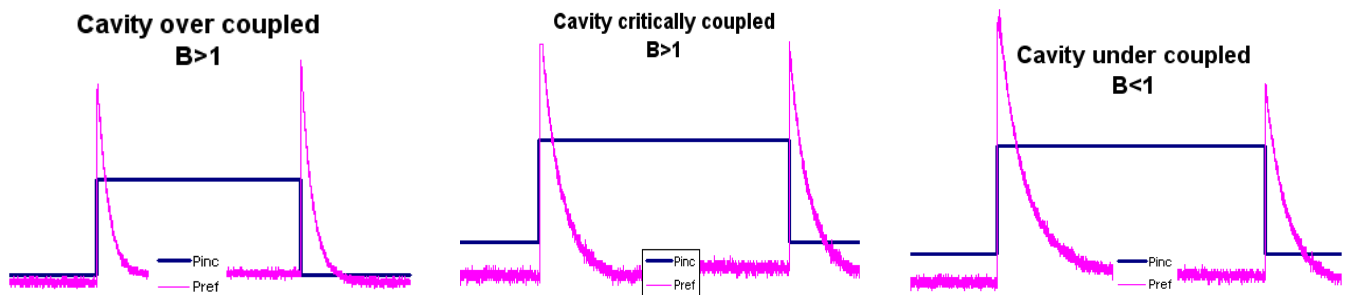
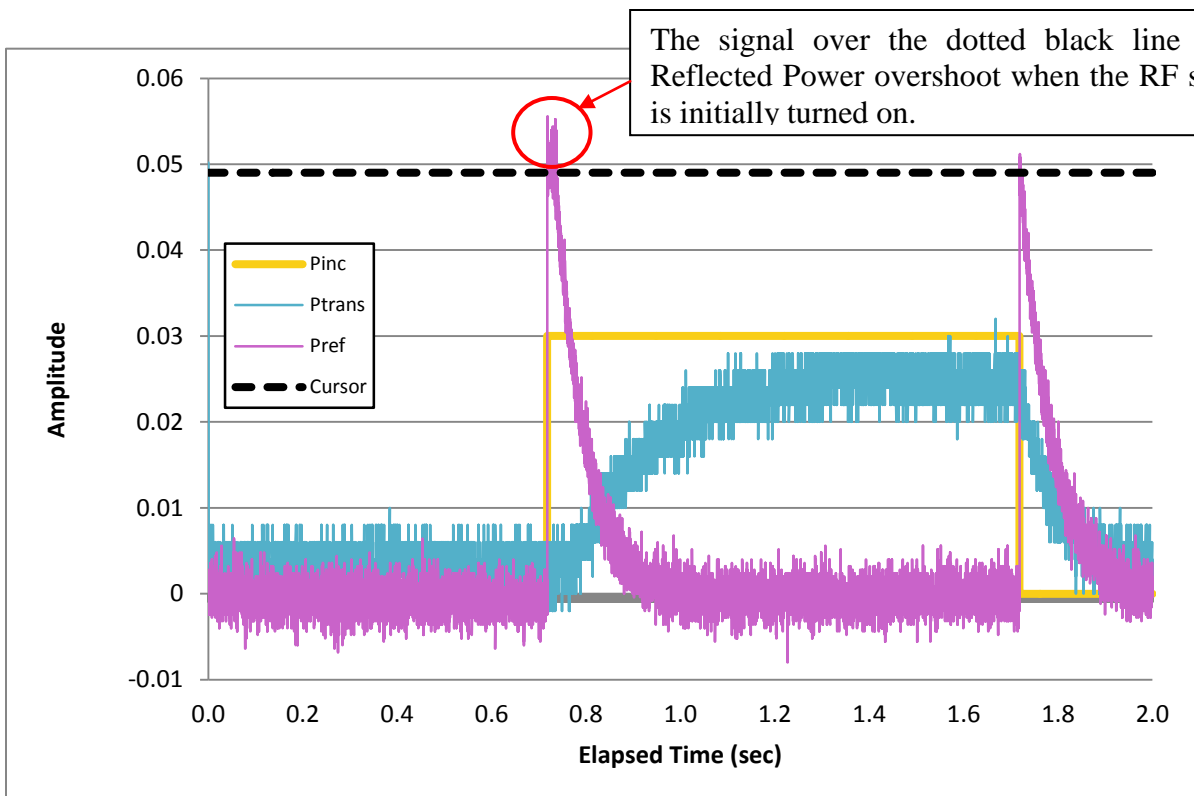


Figure 9 Examples of traces for over coupled, critically coupled and under coupled cavities.

- l. Write down the coupling in the logbook.
- m. Turn **OFF** pulse mode in the **VTA_main.vi** software and press the **Stop/Run** button on the scope to resume scrolling.
- n. Based on this measurement, set coupling switch in **VTA_main.vi** software to $\beta < 1$ (undercoupled) or $\beta > 1$ (overcoupled/critically coupled).
- o. If the cavity is critically coupled or undercoupled, verify the coupling using the method outlined below.
 - Turn **OFF** pulse mode in the **VTA_main.vi** software and turn OFF RF high power.
 - OPEN the 3-way PLL switch labeled ' 0 OPEN 180 '.
 - Wait 10 seconds for the cables to cool down.
 - Turn ON RF high power. On the oscilloscope, note the Reflected Power overshoot.
 - Wait for the Reflected Power overshoot to settle down to a stable reading.
 - Move the oscilloscope cursor so that the cursor sits on top of the steady reflected power signal, just below the noise level.
 - Move the 3-way switch labeled ' 0 OPEN 180 ' to the 0 position to close the PLL feedback loop. Relock the cavity and peak the transmitted power using the phase knob.
 - Repeat the coupling measurement using the 'Pulse Mode' tab in software and turn **ON** pulse mode. If the cavity does not relock after the Pulse Mode turns RF power back on, relock the cavity manually by adjusting the fine frequency knob on the PLL chassis. Do not continue with this measurement until the cavity consistently relocks independently once RF power is pulsed on.
 - When the scope displays a decay shape on reflected power, press the **Stop/Run** button on the scope to stop scrolling and freeze the screen.
 - Note the relative amplitudes of the reflected power peaks. Use the cursor setting as the corrected first peak (RF power pulsed on) value and compare the cursor line with the second peak (RF power pulsed off). If the second peak is greater than or equal to the cursor line, a cavity coupling of overcoupled should be used. See graph below for an example.



This cavity initially appeared to be undercoupled but, after the outlined verification process, it was determined to be overcoupled.

5. Decay Measurements to Determine Q_{ext2}

- a. In software, set $Q_{ext2} = 0$. The ‘Measure and Log’ button label will change to ‘Decay 100% to 95%’.
- b. Set attenuator control to the Reference Attenuation Setting (see Step 2c). This helps to minimize RF amplitude dependent measurement errors.
- c. Tune the manual phase shifter to maximize transmitted power.
- d. IF FIELD EMISSION IS GREATER THAN 0.01 mR/h, the measured values will be field emission loaded. Reduce gradient until field emission is less than 0.01 mR/h.
- e. Press ‘Decay 100% to 95%’. The RF system will perform a decay measurement. A window will appear with the decay curve. Close the window when the measurement is complete.
- f. In the main LabView VI screen, switch to the tab labeled ‘Last Logged Point’ and write down in table format: E_{acc} , Q_o , Q_{ext1} , Q_{ext2} , %Error, radiation, and Q_{HOMA} and Q_{HOMB} (if HOMs are used) in the logbook.
- g. If cavity is no longer locked, retune the cavity and maximize transmitted power and peak the P_{TRANS} with phase optimization.
- h. Complete *at least five decay measurements* to obtain Q_{ext2} .
- i. After each decay measurement, record in table the data set E_{acc} , Q_o , Q_{ext1} , Q_{ext2} , %Error, radiation, and Q_{HOMA} and Q_{HOMB} (if HOMs are used) in the logbook.

Typical values during decay measurements for:

1. E_{acc} = (5+/-1) MV/m
2. Q_o = 1.2 – 1.6 e10
3. Q_{ext1} = 0.8 – 1.2 e10
4. Q_{ext2} = 0.8 – 1.4 e12
5. %Error = 8-13%
6. Q_{HOMA} $\geq 3e12$
7. Q_{HOMB} $\geq 3e12$

- j. Circle in the logbook the Q_{ext2} and the %Error to be used for cavity performance measurements. If multiple data sets are within 2% of each other, the Q_{ext2} and the Q_{ext2} %Error can be selected from one of the agreeing data sets.
- k. In software, enter the measured Q_{ext2} and Q_{ext2} %Error. The ‘Decay 100% to 95%’ button label will change to ‘Measure and Log’.
- l. In the **VTA_main.vi** screen switch to the tab labeled ‘Live Numbers’.
- m. Verify the gradient (E_{acc}) measured during the decay measurement is ± 0.1 MV/m of the gradient displayed in the ‘Live Numbers’ tab. If not, repeat decay measurements.

6. Cavity Performance Measurements

The test will capture cavity performance data.

- a. Switch to the 'Live Numbers' tab.
- b. Switch to the 'Lorentz Detuning Coefficient' tab (located above the graph) and press the 'press to calculate Lorentz Coefficient' button. The button should then turn green and the Lorentz coefficient will be calculated as the Q_o vs E_{acc} data is acquired. Switch back to the ' Q_o vs E_{acc} ' tab.
- c. Tune the phase where transmitted power is peaked at an initial cavity gradient of 2 MV/m.
- d. Press the 'Measure and Log' button.
- e. Decrement the attenuation slider control such that gradient increases by 0.5 MV/m.
- f. Tune the phase to peak transmitted power for each new gradient value and press the 'Measure and Log' button.
- g. During the RF power tests carefully monitor the following:
 - The cavity test remains inside the allowed limits as outlined below in Section 6.1 (Cavity Testing Constraints).
 - Exercise caution if the CW measurement of incident power is higher than 100 W, especially if the coupling is not well matched, to avoid risk of cable breakdown. Cable breakdown can be diagnosed by changing the 3-way switch to OPEN. If P_{loss} is 50% or more of P_{inc} , turn off RF power to allow cables to cool down. Operating with cable breakdown can permanently damage the cold P_{inc} cable.
 - Limit gradient as necessary to prevent exceeding the limits specified in RWP. Specifically, radiation should remain under 10 R/h (1E+4 mR/h).
- h. In the logbook, record the following information as needed:
 - indications of cavity quenching.
 - gradient when onset of field emission occurs (FE onset, defined to be the first gradient where measured, sustained radiation is $\geq 1e-2$ mR/h).
- i. **After acquiring the 20MV/m Q_o value**, switch back to the 'Lorentz Detuning Coefficient' tab (located above the graph) and note the Lorentz Coefficient. If the Lorentz Coefficient is greater than $-4 \text{ Hz}/(\text{MV}/\text{m})^2$ or less than $-6 \text{ Hz}/(\text{MV}/\text{m})^2$, then
 1. On the 'default view' tab on the left hand side of the main LabVIEW VI, verify that the 1497 cavity type is "REN-LL 7 Cell" and the $\text{sqrt}(R/Q)/L$ value is 42.11.
 2. Restart the cavity test, beginning with cable calibrations (section V: Cable Calibrations).
 3. Check the Lorentz coefficient again at 20MV/m. If the coefficient is still out of range, contact Kirk Davis (#6086) for guidance.
- j. Repeat steps e – h to acquire the Q_o vs E_{acc} up to the cavity limit as described in section 6.1. If cavity required RF processing or the plot data of Q_o vs E_{acc} or Rad vs E_{acc} had discontinuities, clean the graph and repeat steps a-h. The test is completed when the cavity becomes limited. Limits include: administrative limit (actual limit is 27MV/m), quench, radiation, cable breakdown, power; other limits require a D3.
- k. **Cavity Testing Constraints :**
 1. **If the radiation reaches 10 R/h (1E+4 mR/h) stop testing immediately.**
 2. **Do not exceed a gradient of 27MV/m.**
 3. If field emission loading occurs at cavity gradients smaller than 15 MV/m, abort test.
 4. If the radiation is greater than 100 mR/h at a cavity gradient less than 27 MV/m, consider cleaning the cavity by RF processing in the other passband modes (see section m below).
 5. If guidance interpreting cavity testing constraints is needed, contact Kirk Davis (#6086).
- l. If the cavity exhibits high electron activity (radiation), perform cavity RF processing.
 1. Set the attenuation to approximately 23 dB.
 2. Refer to the pi modes recorded in the logbook (see step III). Use the frequency counter to change the frequency to the next lower pi mode.

3. Once the cavity is locked with the new frequency, tune the phase to peak the transmitted power. Slowly increase incident power until the cavity is quench limited or the cavity gradient is at the value as specified in table below:

mode index	max. end cell grad.
7/7-Pi	27.00
6/7-Pi	27.00
5/7-Pi	24.75
4/7-Pi	22.13
3/7-Pi	17.37
2/7-Pi	12.52
1/7-Pi	6.50

It is not necessary to press the ‘Measure and Log’ button during the RF processing.

4. Once a limit has been reached (E_{\max} specified in table or quench), record the maximum incident power, radiation and transmitted power (P_{TRANS}) in the logbook. This data may be analyzed later with the spreadsheet CEBAF_7_cell_PassBandModeAnalysis.xlsx, which can be found clicking on the provided link in [C100-CAV-VTRF](#), as a link in this procedure [CP-C100-CAV-VTRF](#) or in the open access web page at <https://srf.jlab.org/srf/TestMeasurement/TestMeas.html> under *Passband Mode Analysis*.
5. Repeat steps 1-4 as necessary for all pi modes, noting that it may not be possible to lock the cavity on the lowest pi mode frequencies.
6. Clear the LabVIEW Main VI graph and repeat steps a – k to fill in a clean Q_o vs E_{acc} plot.
- m. If cavity is quench limited below an E_{acc} of 25 MV/m, keep the same Q_{extfp} as used for the Pi mode and attempt to find the related unscaled quench fields for each member of the fundamental passband using the procedure outlined above in section m.

7. Q_o vs Temperature data at 20 MV/m

Measure and record the cavity lock frequency and Q_o value for $E_{\text{acc}}=20$ MV/m and dewar pressures of 29 Torr, 25 Torr, 23 Torr and 19 Torr.

HeP (Torr)	Dewar T (K)	Typical Q_o values
29 +/-0.1	2.07	1.0 e10
25 +/-0.1	2.02	1.2 e10
23 +/-0.1	1.99	1.5 e10
19 +/-0.1	1.93	1.9 e10

- a. In the logbook, record the dewar pressure, as measured on the dewar VAT valve controller, and liquid level. Verify that there is sufficient liquid in the dewar to perform the temperature measurements (for C100 7-cell cavities, liquid level > 140 cm).
- b. If the VAT valve controller is in “Remote” mode, go to “Local mode” by pressing and holding the “Local” button until the small signal on the left side of the button is lit.
- c. Directly after completing the Cavity Performance Measurements, the dewar should be at 29 Torr. Use the attenuation slider on the main LabVIEW VI to set E_{acc} to 20 MV/m.
- d. Adjust the cavity lock frequency and tune the phase to peak the transmitted power as needed.
- e. Press the ‘Measure and Log’ Button on the main LabVIEW VI and record the cavity lock frequency and Q_o value in the logbook.
- f. Turn OFF RF Power while lowering the dewar pressure.
- g. Change the pressure set point to lower values by pressing the button with the down arrow in steps of 0.1 – 0.2 Torr. Wait until the pressure in the dewar stabilizes and then continue decreasing the pressure until reaching the final target pressure.

- h. Turn ON RF power. Set the RF power level to 20 MV/m. Set the 3-way switch labeled '0 OPEN 180' to the OPEN position to open the PLL feedback loop. Check that the $P_{\text{loss}}/P_{\text{inc}}$ is less than 0.01. If necessary repeat 'Forward Power to Detuned Cavity' cable calibration until $P_{\text{loss}}/P_{\text{inc}}$ is smaller than 0.01. Record the $P_{\text{loss}}/P_{\text{inc}}$ value in the logbook.
 - i. Move the 3-way switch labeled '0 OPEN 180' to the 0 position. Adjust the cavity lock frequency and tune the phase to peak the transmitted power.
 - j. With the cavity field set to 20MV/m, press the 'Measure and Log' Button on the main LabVIEW VI and record the lock frequency in the logbook.
 - k. Repeat steps f-j for dewar pressure of 25 Torr, 23 Torr, and 19 Torr
 - l. Return the VAT pressure set point to 29 Torr when temperature measurements are completed.
- 8. When the cavity performance measurements are complete:**
- o In the control room, turn OFF high power and switch system to low power RF.
 - o Inform via email the VTA Lead Maintenance Operator about the disposition of the test.
 - o Record the cavity test result (limiting factor, maximum radiation, E_{acc} and Q_o from Step 6: *Cavity Performance Measurements*) in the VTA Operational Safety Log Book.
- a. In the main LabVIEW VI, press **Backup files**. This will save a copy of the oscilloscope data and RF test data on the M Drive. M:\asd\asddata\VTA_RF_DATA\1497_DATA\RAW_DATA\
 - b. If no other Dewars are being used for high power testing:
 1. Switch the PSS system to the disabled state with the key.
 2. Open the Dewar lid and return the HOM Power Meter to its storage container.
 3. Take down the Radiation Warning signs and OPEN the gate.
 - c. If other Dewars are being used for high power:
 1. Inform the other RF operators that your test is complete.
 2. Open the Dewar lid and return the HOM Power Meter to its storage container.
 3. Leave up all Radiation Warning signs and the gate CLOSED.

VII. How to fill out the cavity performance traveler

A. Processing data

During VTA test, a text file with raw data is generated. The complete data file name is generated during in Part V6 of this procedure, and consist of the cavity ID number, associated with a letter if cavity has been tested several times, (“A” is added if cavity has been tested twice, “B” is added if cavity was tested three times and so on) with a “.txt” extension. The raw data file can be found on the 1497MHz RF testing computer C drive at C:\Labview Data\Cavity Test Data or M:\asd\asddata\VTA_RF_DATA\1497_DATA\RAW_DATA\Cavity Test Data.

1. An Excel workbook is used to process the raw RF test data. Several links are provided to download the workbook: one in [C100-CAV-VTRF](#) , another link in this procedure or in the open access web page <https://srf.jlab.org/srf/TestMeasurement/TestMeas.html> under *RF Processed Data*.
2. Open C100_RI_000_Processed Data.xlsm and select the **READ ME** worksheet tab.
3. Click on the *Import Raw Data* button and select the raw data file to process. This will also rename the workbook in the format CavID_Processed_Data.xlsm in the same directory as the imported file.
4. Go to worksheet tab **data cond** and verify that the Start Row (cell F7) and End Row (cell G7) are correct for the current data set. If not, enter the correct Start Row in cell B3 and/or the correct End Row in cell D3. For more information about this worksheet, read the **READ ME** tab.
5. In the **data cond** worksheet tab, enter the cavity ID (this should match the raw data file name) in cell H1, the test date in cell H2, and any test comments (limiting factor) in cell J1.
6. On the **data cond** worksheet, note the start and end row numbers for the Low Field Decay Measurement data and verify that the correct row numbers are showing in worksheet tab **Low Field Decay Calc** cell B5 and D5 respectively. If not, then the correct start row number should be entered into cell B4 and/or the correct end row number should be entered into cell D4. This worksheet will calculate average values for the low field decay measurements and use this average in the ‘Qo & R vs Eacc’ chart. Once the correct Low Field Decay data is displayed in the yellow text box, check the checkbox located to the right of the Overrides.
7. Input the measured Qo values for the temperature measurements in the **Temperature Data** tab.
8. Go to worksheet tab **Traveler Info**. If RF processing or multiple data runs were performed, enter the row number (from **data cond**) that the initial data run began in cell B3 and ended in cell D3. If RF processing was not needed, leave cells B3 and D3 blank. Click the *Calculate Traveler Information* button. The Traveler information will then be calculated and displayed. It is important, however, to verify that the calculated values displayed are correct.
9. The workbook will generate the graphs needed for the Traveler in the following tabs. Verify that the graphs are displaying the data and title correctly.
 - a. Qo vs Eacc
 - b. Rad vs Eacc
 - c. HOM A and B vs Eacc
 - d. Qo & R vs Eacc @ 2.07K
 - e. Delta Freq vs Eacc²
 - f. Qo vs T
10. Generate pdf files of the graphs using the following naming conventions and save all graphs to M:\asd\asddata\VTA_RF_DATA\1497_DATA\RAW_DATA\Cavity Test Data. The CavIDx should match the name of the raw data file generated by LabVIEW in step V6 (i.e., C100_RI_001A). The Excel template has a built-in macro to create and save the pdf files automatically; from the **READ ME** tab, press the *Create PDFs* button.

a. CavIDx_QvsEacc.pdf	d. CavIDx_QandRadvsEacc.pdf
b. CavIDx_RadvsEacc.pdf	e. CavIDx_FreqvsEacc2.pdf
c. CavIDx_HOMaHOMbvsEacc.pdf	f. CavIDx_QovsTemp.pdf
11. Save the workbook with the same file name but with an “.xlsx” extension (save without macros).

B. Fill out Traveler

1. To fill out the traveler, log on to Pansophy: <http://pansophy.jlab.org/pansophy/>
2. From the 'Traveler' pull down menu, select SRF CEBAF→C100→Input Data Into Traveler
3. Select C100-CAV-VTRF-R4.
4. Press the **NEW** button in the upper right hand side. A blank traveler form will be displayed.
5. Enter the Cavity ID and other test information in the fields displayed.
6. Press the **INSTANTIATE** button at the bottom of the page.
7. A Traveler sequence number has now been assigned to this Traveler. The sequence number is displayed in the upper right hand side of the page: TRAV_SEQ_NUM: ###. Record the sequence number in the logbook.
8. Click on the **Next** button at the top of the page.
9. Continue to fill in the information from the HOM survey and RF test in the Traveler. Press the **Submit to Database** button at the bottom of each page before progressing to the next page.
10. Leave Step 12: Cavity Meets HOMs Specifications blank. This will be filled by the HOM survey reviewer after he/she has approved the cavity.
11. Leave Step 31: Cavity Meets Specifications blank. This will be filled by the cavity performance reviewer after he/she has approved the cavity.
12. Some fields will require files to be uploaded and attached to the Traveler. Press the **Attach Files** button. Another tab will open. Under 'Upload a new file.' press the **Browse** button. A file dialog box will appear. Select the file to be uploaded and press OK. Then press the **Attach File** button. Once the file name will show up under the Browse button, press the **Post Entry >>** button. The new tab will then close and the Traveler with a link to the file displayed.
 - a. On Step 14: Cavity Coupling, the oscilloscope data file can be found in
M:\asd\asddata\VTA_RF_DATA\1497_DATA\RAW_DATA\1497MHz oscilloscope data
 - b. On Steps 25-29, files can be found in
M:\asd\asddata\VTA_RF_DATA\1497_DATA\RAW_DATA\Cavity Test Data
13. Generate NCR if the cavity or HOMs performed below specifications. Document non-standard test procedures using a D3.

you have been authenticated
who am i click here to logout

Travelers Logbooks Support DocuShare

CEBAF-Upgrade
Traveler Input Mode

Select Traveler Page 1 First Previous Next Last NEW

SerialNum: 0 C100-CAV-VTRFR3 Pg: 1 TRAV_SEQ_NUM: 0

Step No.	Instructions	Data Input
1	Input C100 CEBAF 7-cells cavity ID. Note any special handling, processing (chemistry or bake) or off-normal	CAVSN -0- SpecialHandling

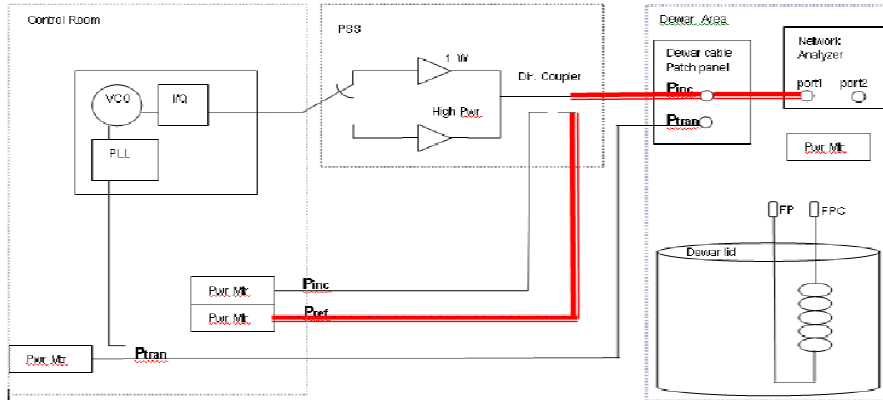
VIII. Supplemental

A. Power into Control Room Measurements

1. Power Out from Network Analyzer

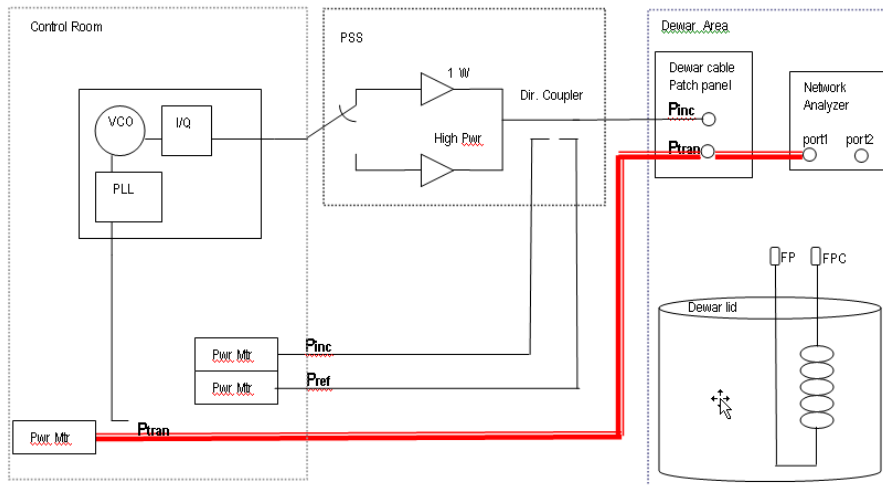
2. Reflected Power from VTA

Block diagram representation of ‘Reflected Power from VTA’ cable calibration step.



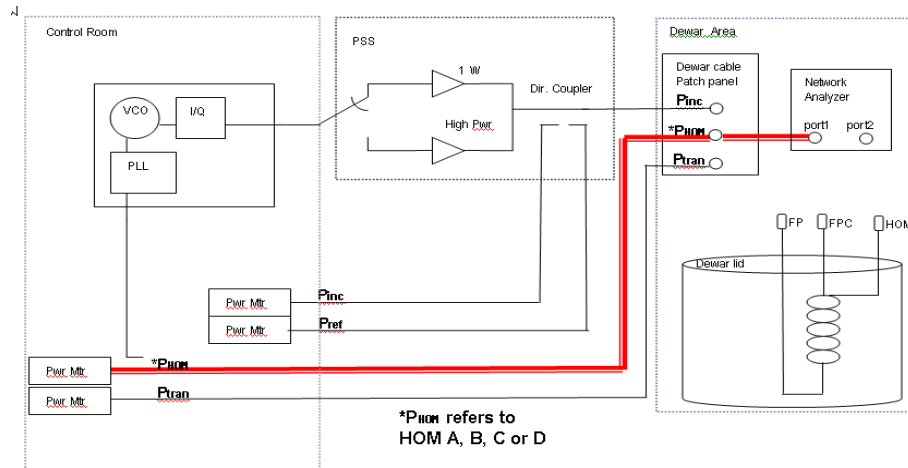
3. Transmitted Power Into Control Room

Block diagram representation of ‘Transmitted Power Into Control Room’ cable calibration step.



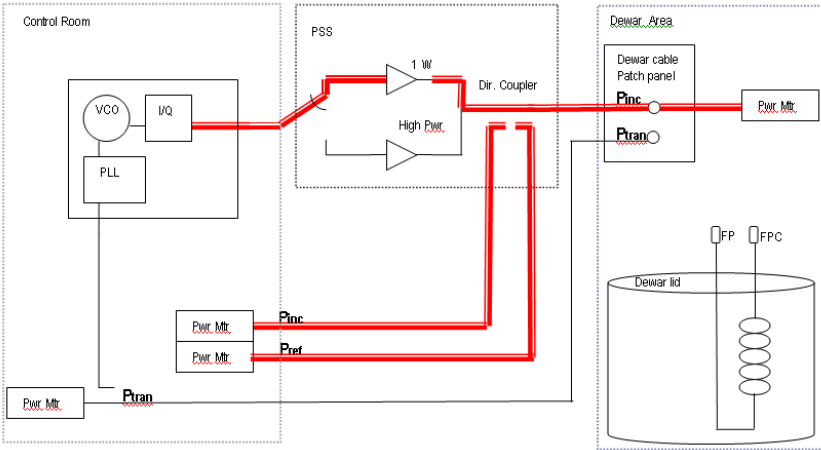
4. HOMA (HOMB) Power Into Control Room

Block diagram representation of ‘HOMA (HOMB) Power Into Control Room’ cable calibration step.



B. Incident Power at Dewar

Block diagram representation of 'Pi at Dewar' cable calibration step.

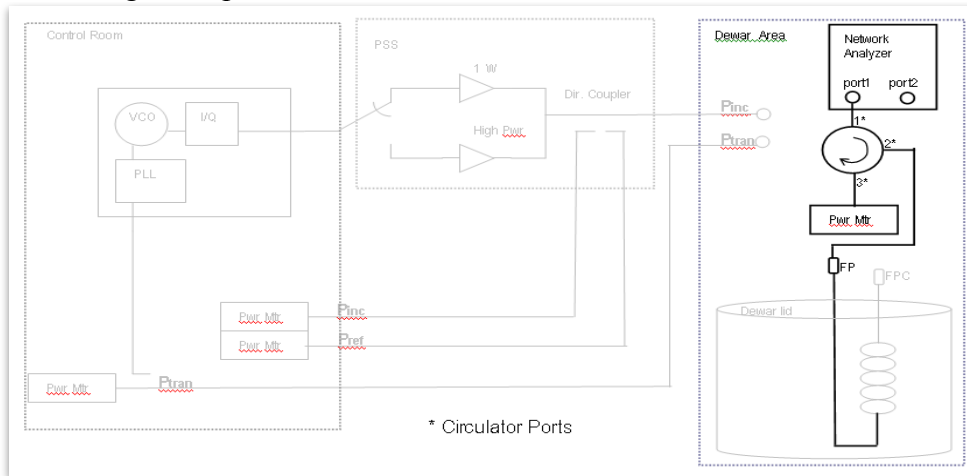


C. Cable Return Losses

1. Calibrated Open Measurement

2. Transmitted Cable Return Loss

Block diagram representation of 'P_{TRANS} Cable Return Loss' cable calibration step.



3. HOMA (HOMB) Cable Return Loss

Block diagram representation of 'P_{HOMA} (P_{HOMB}) Cable Return Loss' cable calibration step

