LLRF RF channel calibration

1/24/19

This procedure is used to perform a field calibration of the LLRF chassis and cables associated with LCLS2: RF Stations, and Precision Receiver Chassis. These steps will

1. measure the magnitude gain of the receiver chain at a single frequency and power level as driven by a power source with a 50 ohm source impedance
2. Measure the magnitude gain of the cable plus the receiver chain at a single frequency and power level as driven by a power source with a 50 ohm source impedance

This procedure is not a complete analysis of the RF network, but is intended to provide a "good enough" measurement of the system losses and signal stre

The LO signal strength supplied to each chassis affects calibration. It should be stable and an appropriate strength, approximately 10 dBm. This signal is monitored and can be checked in EPICS prior to calibration.

A. At the back of the RF chassis

1. Connect an RF source with approximately 10 dBm to the RF channel for calibration
2. Ensure that the frequency of the source is close enough to the chassis DDSA setpoint by checking the phase waveform of the signal. No or few phase wraps should be visible.

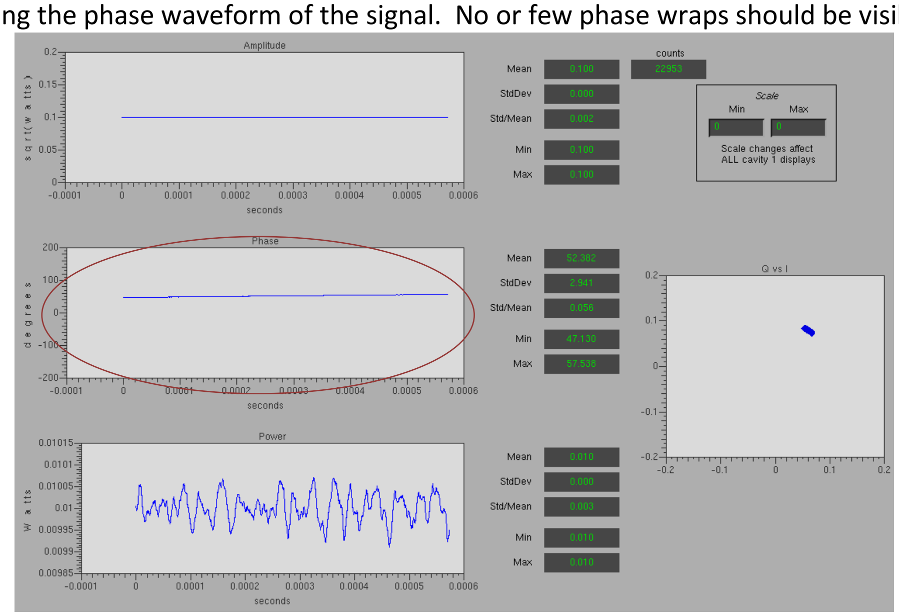


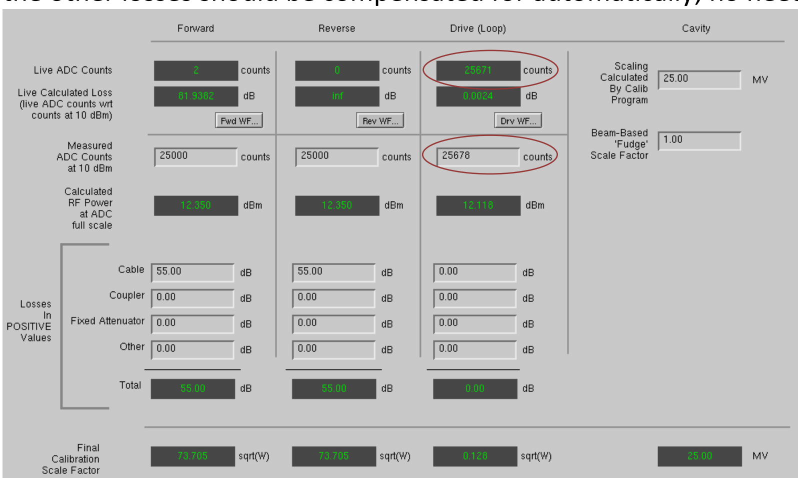
Figure 1: Signal ready for calibration. Frequency is close to DDS, so small phase change through waveform

3. Disconnect the RF source and connect it to a power meter for calibration. Set to 10 dBm.
4. Re-connect the 10 dBm source to the back of the RF channel for calibration.
5. Record the digitizer mean amplitude in counts and use that value for extrapolating to full scale.

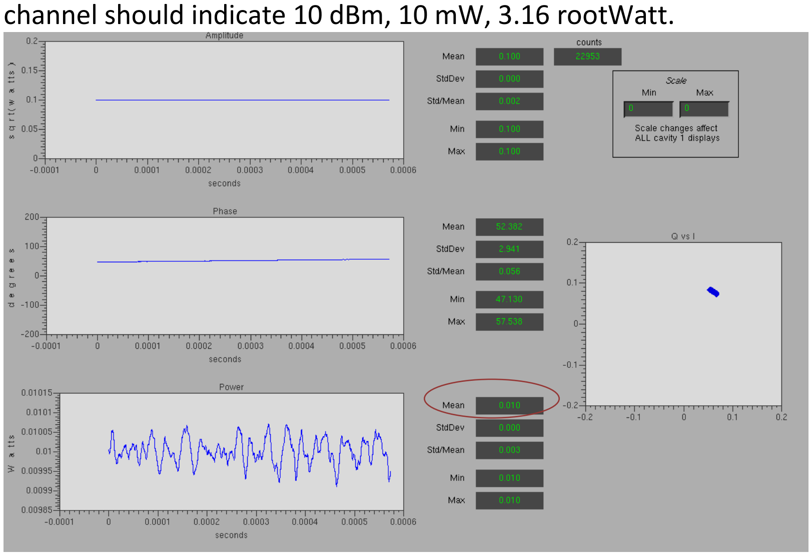
$$dBmFS = 10\ dBm + \mathrm{dBFS@10} - other\ calibration\ losses$$

$$dBFS@10 = 20\log_{10}\frac{32767}{ADC@10}$$

Where dBmFS is the maximum measureable power for the channel, and ADC@10 is the ADC counts measured with a 10 dBm input. Other calibration losses will typically all be set to 0 during this measurement, if not make sure that are accounted for. If using the readout in EPICS, the other losses should be compensated for automatically; no need to set to 0.



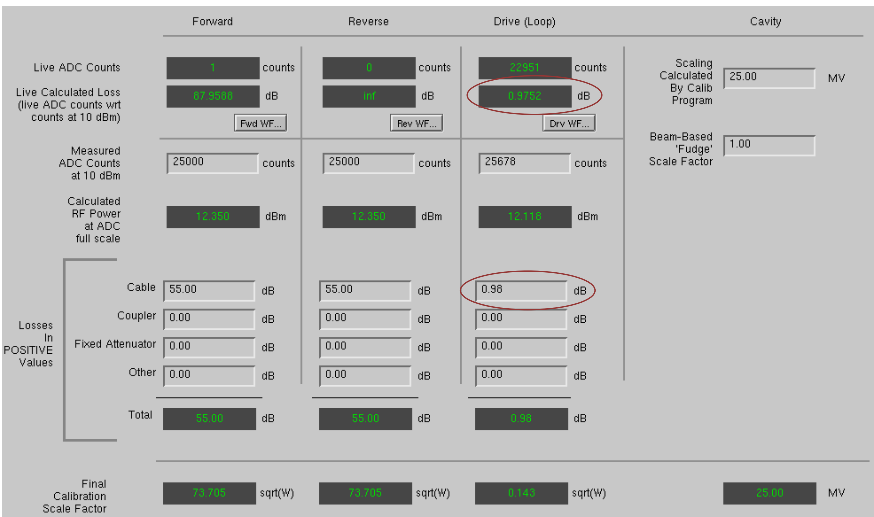
6. Check: the full scale in dBm should be close to 12 dBm, the current power readback of the channel should indicate 10 dBm, 10 mW, 3.16 rootWatt.



7. Repeat steps 4 – 6 for each channel for one chassis within a few minutes to maintain source calibration. If testing a second chassis, recalibrate both frequency and amplitude with steps 1 – 3.

B. At the far end of the RF cable

1. Connect an RF source with approximately 10 dBm to the RF cable for calibration
2. Ensure that the frequency of the source is close enough to the chassis DDSA setpoint by checking the phase waveform of the signal. No or few phase wraps should be visible.
3. Ensure that all calibration values are set to 0, and that no added attenuation exists.
4. Disconnect the RF source and connect it to a power meter for calibration. Set to 10 dBm.
5. Re-connect the 10 dBm source to the RF cable for calibration.
6. Record the digitizer input in dBm. 10 dBm minus the recorded value is the cable loss. This should be about 10 dBm – 8 dBm = 2 dB for a heliax cable that is 15 m long. The value is independently displayed in EPICS.
7. Enter the cable loss into the cable calibration field.



8. The calibrated power measurement should now indicate 10 dBm, 10 mW, 3.16 rootWatt.

$$dBm = dBmFS\ (dBm) + cable\ loss(dB) + other\ calibration\ values\ (dB) - dBFS(dB)$$

Where dBmFS is the channel maximum power in dBm, and dBFS is the current measured power as a part of full scale

$$dBFS = 20 \log_{10} \frac{32768}{ADC}$$

C. Full calibration

1. Enter the factory calibration factor for the directional coupler signal or the cavity calibration factor for the cavity probe into the calibration field.
2. Make sure that the peak theoretical calculated power is not less than about 5 kW
    - Typically this means that $calibration\ coef \geq 10 \log_{10} \frac{5000}{.01} = 57\ dB$
3. If the total calibration coefficient is less than 57 dB, attenuation should be added to the back of the chassis and added to the fixed attenuator calibration field.

Figure 2: Calibration screen interface.