T41 Calibration Directions

Several functions of the T41 require calibration at the outset before putting the radio into service. More robust calibration routines are now included in the latest T41 software for the V12.6 and later hardware. As of this writing the latest version is V66.8. These routines include calibration of several key parameters:

- Frequency
- Receive IQ calibration
- Transmit IQ calibration
- CW transmit power
- SSB transmit power
- SWR and Power readouts

Some external measuring devices or sources may be required for the best results, including

- Standard RF frequency source and/or reception of WWV or CHU, etc.
- External HF receiver or spectrum analyzer
- RF power meter

Since calibration does not have to be done frequently, the user may elect to borrow or share these resources with other amateurs.

Naturally, the quality of the calibration results depends on the accuracy of the standard measuring device or source.

The initial T41 setup should be performed in the following order:

1. Frequency calibration
2. Receive Calibration
3. Preliminary SSB PA Power calibration to ensure levels are nearly correct
4. Transmit IQ calibration
5. CW PA Power level calibration
6. Check SSB PA Power calibration one final time
7. Perform SWR and Power readout calibration

Frequency Calibration

Frequency calibration of the T41 local oscillator (LO) requires an external RF frequency standard source such as WWV or a calibrated signal generator or a standalone source such as a Rubidium Frequency standard. The resulting T41 frequency accuracy is dependent on the accuracy of the source. WWV (or others) is best if a strong signal is available on one of the several standard frequencies.

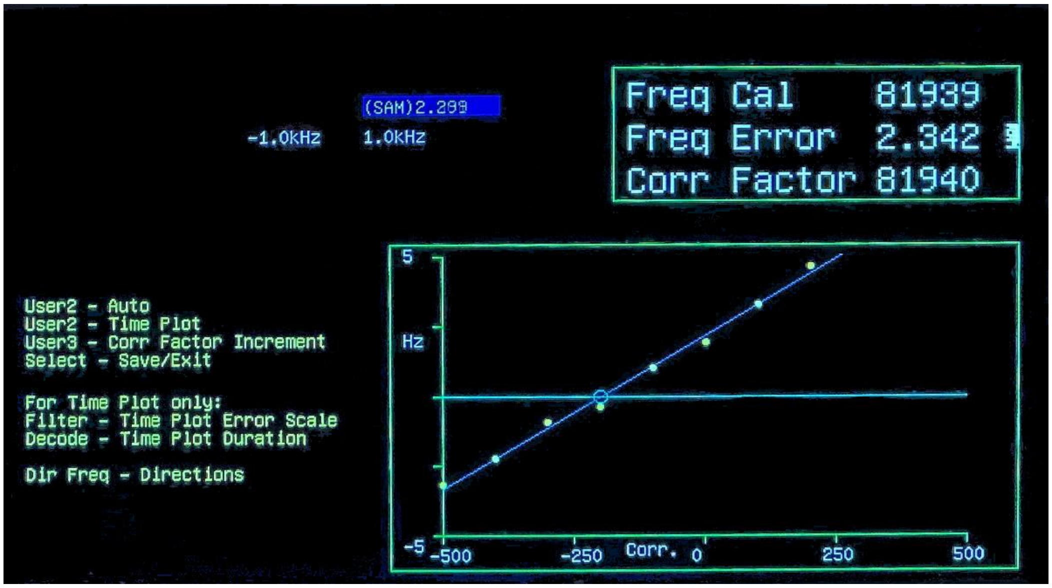


Figure 1 Auto Frequency Calibrate Crystal Reference

V12 T41 RF board has the option of using a TCXO (Temperature Controlled Crystal Oscillator). It is important to make sure that the Si5351 reference is either a TCXO or a 25MHz crystal – not both. Having both will yield a situation in which the unit cannot be calibrated.

Note on using WWV or other HF standard broadcasts:

WWV broadcasts on several frequencies in the US, such as 5MHz, 10MHz and 15MHz. Outside the US other standard frequencies are available, such as CHU in Canada on 3.33MHz, 7.85MHx and 14.67MHz.. These stations transmit a variety of information, such as one minute tics and spoken information. Periodically the one second tics are turned off and only the standard carrier is transmitted. This is the best time to make final adjustments. Patience is also required for the best results.

The suggested WWV process is as follows:

- Tune to the strongest WWV (or other) signal at your location.
- Set the Filter to 1KHz or less.
- Select SAM demodulation *prior* to starting the frequency Cal routine
- Manually tune for the lowest error during the regular broadcast.
- When the error is close to 0.0, use the Auto Tune function to complete the process. With crystal Si5351 reference (no TCXO), several Auto adjustment cycles may be necessary.
- It is possible to skip the manual tune steps and use several Auto Tune passes instead, in which case the plots will not be correct until the correction factor has brought the LO to within a few Hz of the standard..

Frequency Calibration details

The T41 Frequency Calibration routines provide tools to allow the LO calibration to be adjusted as closely as possible to the selected frequency standard. These tools utilize a demodulation function called SAM – Synchronous Amplitude Modulation. The routine compares the internal LO frequency to the receive frequency and displays the difference in Hz. This approach appears to be accurate to better than 1Hz during routine T41 use. In fact, with the optional TCXO, the SAM function in the frequency calibration routines appears to allow setting the T41 LO to better than 0.1Hz. A linear regression process is used to determine the best Frequency Correction Factor for either crystal or TCXO reference.

Figure 2 Auto Frequency Calibrate TCXO

The frequency calibration tools include the following:

- Display of the current Si5351 correction factor and the calibration difference in Hz.
- Manual adjustment of the Si5351 correction factor using the Filter encoder to change the correction factor.
- Auto-calculation to the best correction factor uses linear regression. The Si5351 frequency output is a linear function of the correction factor. The zero error point is found by varying the applied correction value while measuring the frequency error and then creating a linear regression trend equation to predict the zero error correction factor value. Figure 1 shows the linear regression plot for a crystal reference fir the Si5351. Figure 2 shows the result for a TCXO reference.
- Plotting of Frequency difference vs. correction factor created by:
  - Automatically varying the Correction Factor and computing the best value for minimum error, using a linear regression routine.

- A time plot of the frequency error versus time at a specific Si5351 Correction Factor is also included. This plot allows verification of the Frequency Calibration Factor value over selectable periods of time. Figure 3 shows a T41 TXCO frequency stability plot for an 8 hour period. The T41 Frequency offset is about .03Hz, with a Standard.Deviation of .023Hz. The reference source is a Rubidium 10MHz frequency standard.

Figure 3 TXCO 8 hour Frequency Error Plot

To make the most effective use of these tools, it is suggested that the process should be applied as follows:

- Allow the T41 and the frequency standard to warm up for at least 30min.
- For best results the T41 should be in a closed case to minimize temperature variations.
- Set Filter to 1KHz.
- Set the T41 Demod to SAM.
- Select Calibrate/Freq from the T41 menu.
- After the T41 Frequency Calibration is initiated, first manually adjust the correction factor with the Filter encoder for minimum frequency difference as a starting point. (This can be bypassed, but then several additional iterations of the Auto function may be necessary. (The error plot will only be correct when the LO is within a few Hz of the standard.)
- With the Auto-plot routine, a frequency difference vs correction factor plot is created. Note the displayed recommended Correction Factor.
- Repeat the plot several times and use the Correction Factor values that give the lowest frequency error if there is variation because of noise on the signal.
- Set the Correction Factor to the best value just calculated if different from the displayed value.

- Then observe the T41 frequency stability using the time plot. With the TXCO, if the result is not less than +/- 0.5 Hz over a reasonable period of time, the process should be repeated.
- On-screen directions are available by pressing “Dir Freq” button.
- Press “Select” to exit and save the Frequency Correction factor to EEPROM.

Additional notes on the process:

- The nature of the T41 with the optional TXCO, based on a limited sample, is that the frequency stability is better than +/- 0.1 Hz over at least a day.
- Frequency stability with crystal reference is several times worse, on the order of 0.5 to 1Hz variation over a period of hours, depending on the change of temperature in the case.
- On a short term basis, the frequency difference appears to vary randomly around the set point as much as approximately +/- 0.07Hz, so manually setting the correction factor is not precise. Because the Si5351 output frequency is a linear function of the correction factor, a linear regression approach yields better results. For this reason the Auto Calibration option is preferred.
- As mentioned, temperature variations may cause the LO frequency to vary. For instance, Figure 4 shows the result of opening and closing the T41 case during the plot time with a TCXO. The plot duration is approximately 1.3 hours.

Figure 4 Effect of Temperature Variation

- Using a TXCO makes a large difference in the frequency stability over time, as shown in Figure 4. In this case the error is plotted for a 25 MHz crystal instead of the TXCO. Compare Figure 5 to Figure 3. The TXCO average mean over 8 hours was 0.034 Hz, compared to the crystal average mean of 0.367 over just 1.3 hours. Average Mean is computed using all of the samples, while the Running Mean is calculated using a running average over 20 samples.

Figure 5 Crystal Frequency Error

Receive IQ Calibration

Receive calibration is self-contained, requiring no external equipment.

Why IQ Calibration?

The Quadrature approach to demodulation of SSB signals requires that the two quadrature signal paths, I and Q be balanced in both gain and phase in order to reduce or eliminate unwanted “images” of the desired signals. Gain and phase differences arise from the tolerances of parts in the summing amplifiers and antialiasing filters. These slight differences are compensated for in the Receive Calibration factor applied to the digital signal. The variations are also frequency dependent, so calibration of each frequency band is necessary.

The current version of Receive Calibration has been completely rewritten for V12 hardware to better use the regular Receive DSP calculation process. The resulting calibration has been verified using external signals to determine that minimization of IQ images agrees with the calibration result.

The reference signal for Receive calibration is provided by using the T41 CW output from Si5351 CLK2 through the T41 V12 attenuators.

Setup is as follows:

- Disconnect the T41 antenna input.
- On the RF board, jumper J4 (Cal Isolation jumper) on the V12.6 RF board.
- Select the Band to calibrate.
- Select a frequency either near the band center or near specific operating frequencies.
- Select the Menu item: Calibration/Rec Cal.

- Verify that the signal level shown in the blue band is about the mid-point or higher on the display.
- Figure 6 shows the Receive Cal screen, with starting values of Gain=1.0 and Phase=0.0.
- Minimize the IQ Image level in the Red block and IQ Image level (adjdB) readout:

Figure 6 Receive Calibration Before

- Option 1 Manual adjustment
  - Alternately adjust IQ Gain and IQ Phase with the Filter and Volume encoders.
  - Use User3 to toggle the adjustment increment. Increments are 0.1, 0.01 and 0.001.
  - adjdB readout shows the ratio of the IQ Image to the input reference in dB. Better than -50dB should be attainable.
- Option2 Auto adjustment
  - Press the Decode Button to calculate the parameters. Figure 7 shows the Auto Cal in progress.

Figure 7 Auto Cal in Process

- Repeat, if necessary, especially when the initial image level(red) is high. Each Auto cal cycle takes about 75 seconds to complete.
- Press Select to Exit and Save values.
- Repeat for all Bands.

Figure 8 shows the result of inputting an RF reference to the Antenna input from a signal generator, simulating a 1KHz SSB signal at about S9, while in the standard SSB operating mode.

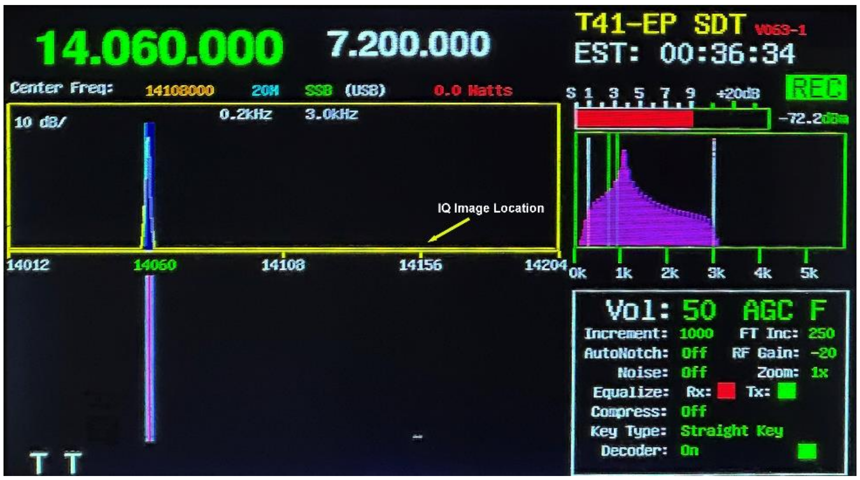


Figure 8 Reference Signal and image After Rec Cal in SSB Receive Mode

The location of the IQ image is indicated on the 1X zoom spectrum. The image is better than 70dB below the reference.

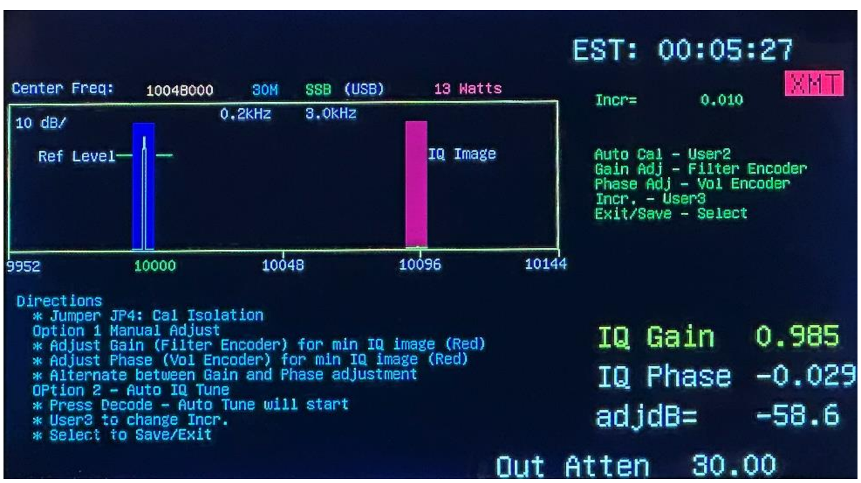


Figure 9 Receive IQ On-Screen Directions

Figure 9 shows the on-screen directions displayed when the DirFreq button is pressed in calibrate.

Transmit IQ Calibration

Transmit IQ calibration requires external equipment to monitor the transmit IQ image. This can be a Spectrum analyzer or a suitable HF receiver, which should be connected to the T41 RF output through a 50 ohm attenuator/dummy load capable of at least 40dB of attenuation and power levels of 15W.

Figure 10 shows the 40M hookup details as an example. Other bands require different frequency settings.

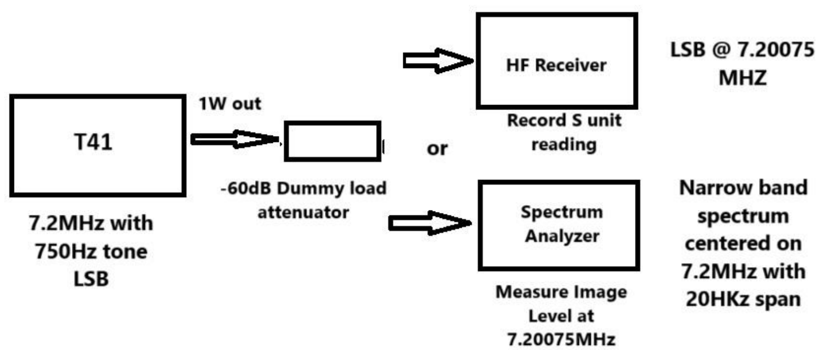


Figure 10- Xmit Calibration Hardware Setup

Calibration steps:

- Remove JP4 jumper on RF board.
- Set T41 to 7.2MHz LSB or any other band center.
- Select Calibrate/Xmit Cal from the Menu.
- Plug in a switch to the PTT jack.
- If using an external receive set the receiver as follows:
  - AGC to Normal.
  - For 40M, receiver Frequency=7.2MHz and Sideband to USB or Frequency to 7.200750 and sideband to LSB.
  - Either combination will tune the IQ Image.
  - If the Receiver has narrow band IF capabilities, tune for the narrowest BW that will give a good result when T41 is transmitting the 750Hz tone. The objective is to tune the IQ Image in the adjacent band, not the primary signal.
- If using a Spectrum Analyzer (SA), setup is as follows
  - Set center frequency to 7.2MHz for 40M
  - Set Span to 20KHz and BW to 30Hz.

- Press the PTT switch and set the IQ gain to 0.8. to view the unwanted image on the receiver or SA. Change the IQ Gain adjustment to IQ Phase adjustment using USER3 button and tune for the lowest reading on the receiver S-meter. The IQ image appears to have a broad minimum as the Phase setting is varied.
- Change back to IQ Gain and observe the S-meter reading, shown in Figure 11. The

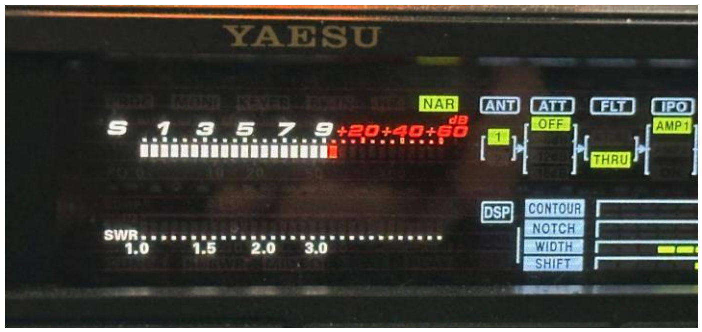


Figure 11 – Receiver S-meter at about .85 IQ gain

narrow-band spectrum is shown in Figure 12.

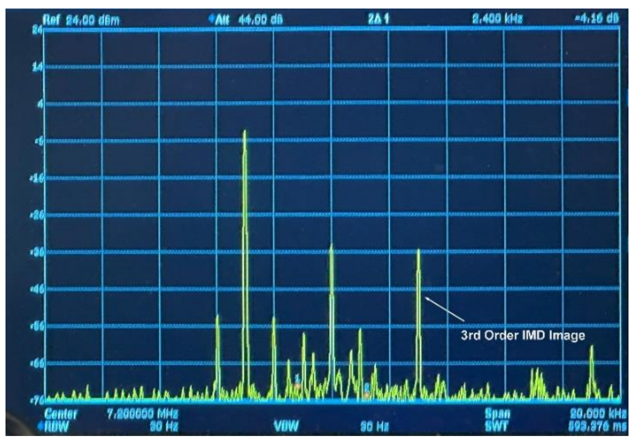


Figure 12 Narrow-band Spectrum Before Calibration

- Switch back to Phase and adjust as necessary.
- Change the IQ Gain and repeat the process.

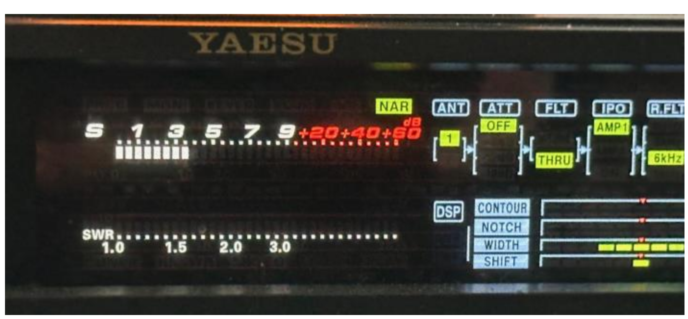


Figure 13- S-meter at Minimum

- Figure 14 shows the SA plot at a minimum.

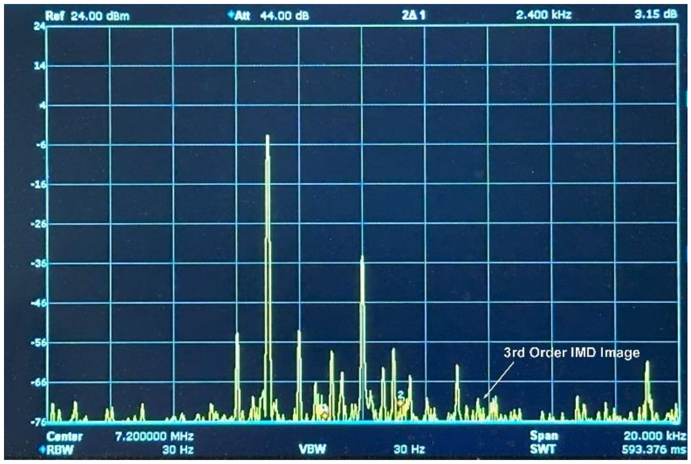


Figure 14 Narrow-band Spectrum After IQ Calibration

- A plot of the S-meter readout vs IQ Gain can be obtained by varying the gain with the Filter encoder, reading the S-meter value and using the Vol encoder to adjust the value to the S-meter reading. Press the Filter encoder switch to plot the point. Repeat for various gain values.
- Use the Volume encoder to set the IQ Image Level value to the observed S-meter reading for plotting.
- Change the increment to 0.001 and tune for the best minimum on the S-meter or SA.
- Press the Filter encoder switch to plot the point.
- A clear minimum should appear on the plot after a few points as shown in Figure 15.

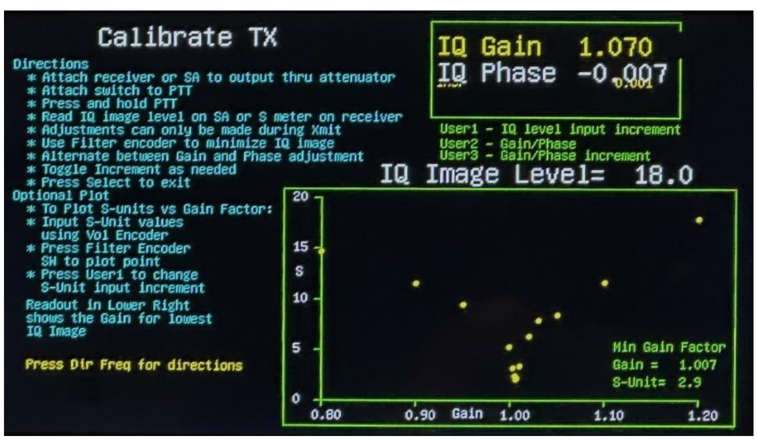


Figure 15 T41 Xmit IQ Gain plot

- On the SA observe the adjacent channel peak at 7.200750MHz and minimize. Figure 14 shows the narrow-band spectrum.
- Once the minimum reading has been obtained, *reset the IQ Gain to the value that gave the minimum* and press Select to exit and save the IQ Gain and IQ Phase values.
- Repeat for the other bands.

- Finally Press Dir Freq Button to display the on-screen Directions which are also shown in Figure 15.

Finally, Figure 16 shows the results for 3 receivers and a spectrum analyzer. Note that the IQ image minimum occurs at the same gain value using each of the receivers and the SA.

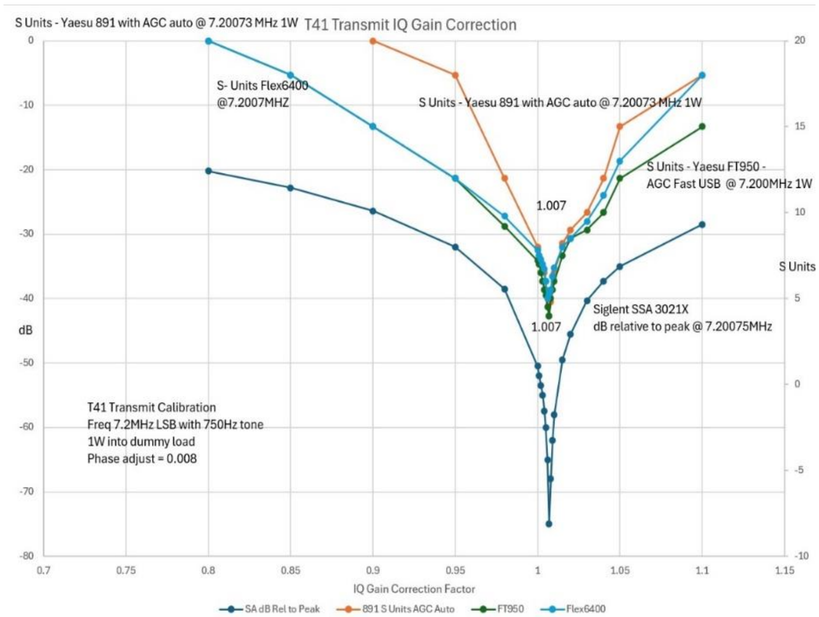


Figure 16 Transmit IQ image minimum

CW and SSB Transmit Power Calibration

T41 transmit power levels are controlled by the setting of the Output Attenuator on the RF board, which is adjusted during the Power Set menu option. Output levels can be adjusted in 0.5dB steps to -30dB. Because there are differences in the RF Exciter levels as a function of frequency, the Calibration routines have options to calibrate the level of CW output and SSB separately and by frequency band.

Please note that because the attenuator has a 0.5dB step, the levels set may be only close the desired set point. Note also that, since the output power is not a linear function of the linear input level, the input value is converted to power using a 3rd or 4th order polynomial function to calculate the output power for a given input.

Power output is a two-step process.

1. Using the Power Set menu option, select a set-point for the calibration, such as 10W.
2. In the calibration function for CW and SSB, separately, adjust the Correction Factors to give the desired power level output on the external power meter.

In the case of CW, the signals are generated internally, while the SSB calibration requires an input to the Mic jack.

CW Power Calibration Detail

- First connect the T41 output to a suitable Power Meter and then to a 50 ohm Dummy Load (DL).
- Connect a key to the Key input jack.
- In the Menu, select Calibrate/CW Power.
- Figure 17 shows the CW Power Calibration screen.

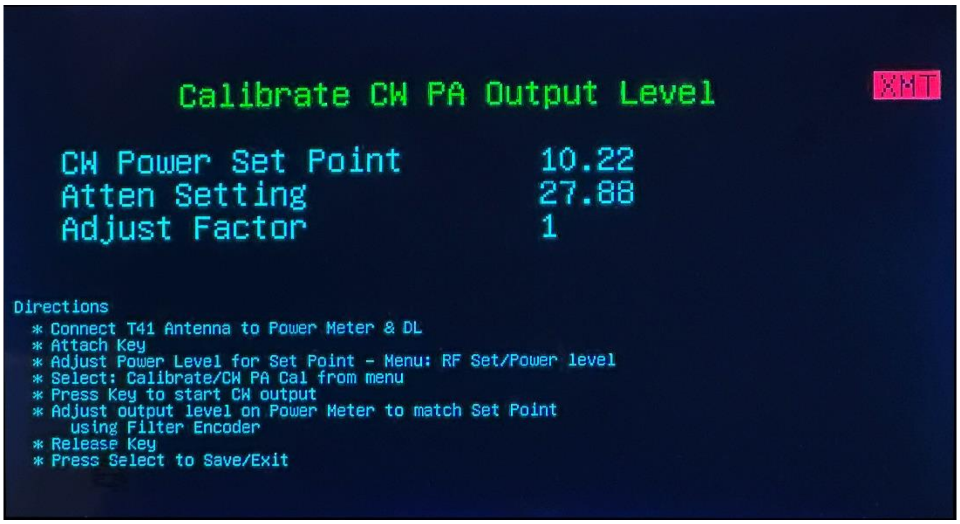


Figure 17 CW Power Calibration

- The CW power set point is shown.
- Press the key and using the Filter encoder, adjust the output as read on the power meter to be as close to the setpoint as possible. Again, because of the available 0.5dB steps, an exact match is not feasible.
- Press Select to save the setting.
- Repeat for the other CW frequency bands.
- Note the on-screen directions.

SSB Power Calibration Detail

SSB Power calibration requires an input source either from a Mic using an audio tone or a Signal Generator input to the Mic jack. The input level from the Signal Generator should be in the range of 10mV to 30mV, depending on the Mic Gain setting. The objective of this calibration step is to adjust the Mic Gain to allow then desired power out for a specific input level. There are two parts to this Calibration step. First the Output Attenuator is set for a nominal output using an internal reference. Then in the regular SSB transmit mode the Mic

Gain is used to set the Power level for an appropriate input. This two step approach is necessary because the user mic or transmit source is different for each user.

- First connect the T41 output to a suitable Power Meter and then to a Dummy Load.
- Connect a signal source to the Mic jack.
- Set an appropriate power-out level in the menu.
- Connect a switch to the PTT input jack.
- In the Menu, select Calibrate/SSB PA Cal.
- Figure 18 shows the SSB Power Calibration screen.

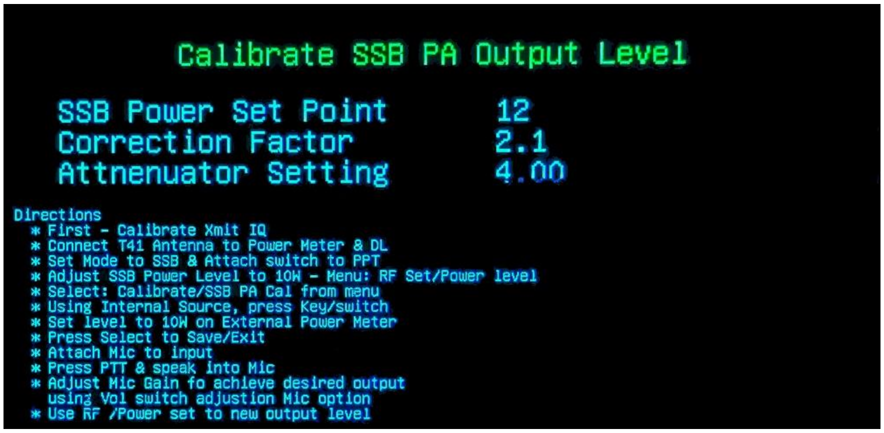


Figure 18 SSB Power Calibrate Screen

- The SSB power set point is shown.
- Press the PTT switch and using the Filter encoder, adjust the output as read on the Power meter to as close to the setpoint as possible for an appropriate input to the Mic Jack.. Again, because of the available 0.5dB steps, an exact match is not feasible.
- Press Select to save the setting.
- Repeat for the other SSB frequency bands.
- On-screen Directions are also shown in Figure 18.
- Once the initial step is completed, connect the mic and in the regular SSB transmit mode use the Mic Gain to set the power level to the desired value. Preferably this should be done with a power meter and perhaps a scope monitor to ensure that the output is not overloaded and the signals are not clipped.

Other Functions

In the Calibrate sub-menu there is an entry for a Two-tone Test signal generation.

Two-Tone tests are frequently run to evaluate the IMD performance of a transceiver power amplifier. This menu pick simply provides the input to allow such a test to be performed. The details of this test are beyond the scope of this discussion but are readily available in the literature. Simply follow the on-screen directions to set up the outputs.

A sub-menu option is also provided to allow setting of different tone frequencies for the SSB IQ transmit calibration and the two-tone test.

SWR and Power Measurements /Calibration

The V12 LPF Control board contains a circuit for SWR and Power measurements on the fly. It consists of a directional coupler to isolate the forward and reverse components of the outgoing signal and a two channel log detector/amplifier to convert the RF to a DC signal proportional to the log10 of the RF value. The DC signal is then passed to a 12bit AD7991 ADC and read by the software using the I2C buss. The circuit was designed by Dr Bill Schmidt, K9HZ, whose description is included in the text.

The SWR/Power measurement section on the K9HZ LPF Control board was designed to measure a power range from either 0-20W or 0-100W, to match the power level of the installed PA and yet still stay within the input range of the AD8307 Log Amplifiers (U14 and U19) input ranges. This could be accomplished by either selecting resistors for the input pads to the Log Amplifiers (R16, R17, R18 for U14, and R22, R14, R25 for U19), or how the coupler/ transformer is wound. We have elected to change the transformer winding for either the 20W or 100W amplifier.

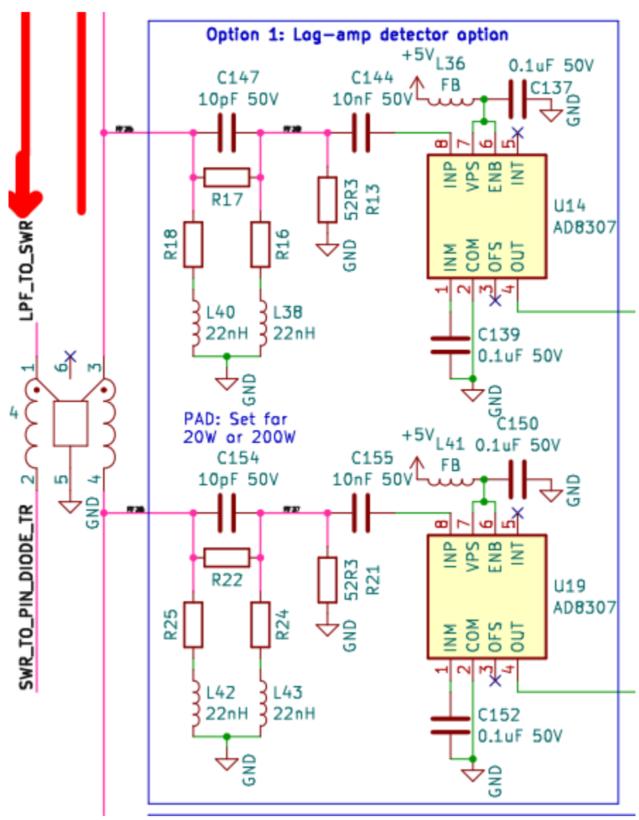
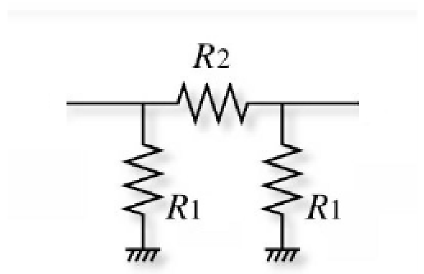


Figure 19 SWR Measuring Circuit

The AD8307 has a nominal conversion slope of 25mV/dB and a zero intercept of -84dBm. The input range of the AD8307 is -75 dbm to +16 dbm. For reference, 20W yields 43 dbm, and 100W yields 50 dbm. For a maximum input of +16 dbm, the AD8307 output is (84+16)*.025= 2.5V. We need to keep inputs to the AD8307 below this value, so we add, in addition to the coupler reduction, an attenuation pad. At 10:1 winding ratio, the coupler has a reduction of 20dB. The attenuation is 10*log(T^2) where T=10. With the coupler alone, the output from the AD8307 would be (84+43-20)*.025= 3.175V at 20W, which is beyond its input capacity of 16dBm (43-20=23dBm). Another signal reduction is necessary, so we add a 26dB attenuator to be able to handle the 20W and 100W amp conditions. (the 100W option requires a 20:1 turns ratio.)

With the 26dB attenuator case, for 20W input we get 43-46 =-3dBm at the AD8307 input. The voltage out is then (84+43-46)*.025= 2.025V, comfortably below the 2.5V max. In the case of the 100W amp, we go to 20 turns, for an attenuation of 26dB. The 100 AD8307 output is then (84+50-52)*.025=2.05V.

Using the equations for a pi-type pad at 50 ohms that give a 26 dbm reduction we can calculate R16=R18 and R22 = R24 values.



$$R1(\Omega) = Z_0(\Omega)\left[\frac{10^{\frac{dB}{20}}+1}{10^{\frac{dB}{20}}-1}\right] \qquad R2(\Omega) = \frac{Z_0(\Omega)}{2}\left[\frac{10^{\frac{dB}{10}}-1}{10^{\frac{dB}{20}}}\right]$$

The schematic shows the option where we change the winding of the coupler from 10 to 20 turns (-20 & -26dB respectively) and use the same attenuator resistor values (498R and 55R2, -26dB) for the 20W and 100W versions.

Using these parameters, it is easy to convert the output of the AD8307 to dBm and power in watts. The calculations in the code are as follows:

First, read the ADC and convert voltage output from the AD8307

```
adcF_sRaw = (float)swrADC.readADCsingle(0);
adcR_sRaw = (float)swrADC.readADCsingle(1)+SWR_R_Offset[currentBand];
adcF_sRaw = adcF_sRaw * VREF_MV / 4096.;
adcR_sRaw = adcR_sRaw * VREF_MV / 4096.;
```

Next, Convert the voltage as read by ADC to the square of input voltage to the coupler

```
adcF_s = (float)pow(10,(adcF_sRaw/(25.+SWRSlopeAdj[currentBand]) - 84 + PAD_ATTENUATION_DB +
    COUPLER_ATTENUATION_DB+SWR_PowerAdj[currentBand])/10)*50/1000;
adcR_s = (float)pow(10,(adcR_sRaw/(25.+SWRSlopeAdj[currentBand]) - 84 + PAD_ATTENUATION_DB +
    COUPLER_ATTENUATION_DB+SWR_PowerAdj[currentBand])/10)*50/1000;
```

Now, do a running average of the square of the input voltage

```
adcF_s = 0.1 * adcF_s + 0.9 * adcF_sOld;  //Running average
adcR_s = 0.1 * adcR_s + 0.9 * adcR_sOld;
adcF_sOld = adcF_s;
adcR_sOld = adcR_s;
```

Then calculate the power input to the couple for both the forward and reverse signals.

```
Pf_W = adcF_s/ 50;
  Pr_W =adcR_s/ 50;
```

Finally, calculate the SWR.

```
float A = pow(Pr_W / Pf_W, 0.5);
swr = (1.0 + A) / (1.0 - A);
```

The AD8307 has a nominal conversion slope of 25mV/dB and an intercept of -84dBm, however, according to the data sheet the slope has a range from 23 to 27mV/dB and the intercept can vary from -87 to -77 dBm. In addition, the channel to channel differences affect the ratio of the forward to reverse power. These uncertainties, plus the other circuit variations, lead to the necessity of applying calibration factors.

The absolute value of the output power in dBm is determined by the attenuations and the calibration factor. In the first calibration step we set this value to a known value at a low power output level of about 10 to 12W.

Next we adjust the slope of the conversion by inputting a higher output level of 1 to 2W and adjusting the slope to yield the appropriate reading. These two measurements interact, so it is necessary to go back and forth the several times to achieve a satisfactory result.

Once we have the calibrated forward and reverse values, we can calculate the SWR. Note that we assume that the two AD8307 units have identical calibration parameters. For the purposes of everyday T41 use, this is probably reasonable.

SWR is defined as

$$SWR=(1+SQRT(Pr/Pf))/(1-SQRT(Pr/Pf))$$

Where

SWR is the Standing Wave Ratio (())
Pr is the reflected power
Pf is the forward power

The ratio of *Pr*/*Pf* if affected by the relative channel offset and slope. We assume the slopes are the same, but the channels may have relative offsets. This is observed by using different values of dummy load resistors. 50 ohms gives a 1:1 SWR reading and 100 ohms yields 2:1. In the calibration process, *SWR_R_Offset;* is used to set the SWR with the 100ohm resistor to 2.0.

Note that, because the 1:1 SWR measurement requires a rather small value for Pr, any noise or offset will affect the result. For a SWR of 1:1 Pr must =zero. Suppose Pf= 10W and Pr= 0.1W, the SWR would be SWR=SQRT((1+.01)/(1-.01))=1.01.

Now if there is a channel to channel difference of 100mV, the effect would be 100/25 = 4 dB. If Pr=100mW and the channel to channel offset is 100mV, which is 4dB, the result would be 0.1W is 20dBm, to which we add 4dB, yielding 0.251W equivalent. The apparent SWR is then SQRT((1+.251/10)/(1-.251/10))=1.025.

The following table shows the effect an offset has on the SWR. Also, the lower the measuring power, the more effect an offset has.

SWR	PowerF	PowerR	Offset mV
1.025442	10	0.1	100
1.065218	10	0.1	200
1.105542	10	0.1	250
1.173319	10	0.1	300
1.52409	10	0.1	400
1.135267	5	0.1	200
1.386272	2	0.1	200
2.102243	1	0.1	200

Step by step SWR calibration

1. Connect the T41 to a 50 ohm dummy load through a SWR/power meter. The DL should be capable of 15W dissipation for the 20W amp.
2. Attach a switch or key to the PTT jack.
3. Connect an external audio source to the Mic jack.
4. Set the mode to SSB.
5. Select from the menu: Calibrate/SWR Cal.
6. Press the PTT switch to start. The existing parameters will be shown.
7. Adjust the external input for 10W out, as shown on the external power meter.
8. Use the *Filter* encoder to adjust the T41 power reading on the screen to 10W, with 10W showing on the external power meter.
9. Adjust the source to yield 2W on the power meter.
10. Now, using the *Vol* encoder, adjust the T41 power reading to 2W as shown on the screen.
11. Because the adjustments interact, repeat steps 8 -10 until a satisfactory result is obtained.

12. Set the power to 5W and observe the SWR. I should be about 1.0 to 1.3.
13. Attrach a 5W capable 100 ohm RF resistor (*not wire wound*) in place of the DL and observe the SWR reading, which should be 2.0. If not
14. Press the User 2 button to toggle the Vol encoder to adjust the Reverse channel offset. Adjust the SWR reading to 2.0
15. When satisfied, press Select to exit and save.
16. Repeat for the other bands.

Conclusion

The new calibration routines for Receive IQ, Transmit Q and Frequency have all been updated and appear to give very good results. Frequency Cal and Receive Cal have both manual and automatic mode. Transmit Cal is only manual, requiring an external measuring device.

SWR calibration is also included.