My procedure to measure frequencies of K5CM:

1. Stabilize the temperature in my Icom 756-Pro II Transceiver. I used 12-volt fans purchased at a local Flea Market. The 12-volt power was obtained from the rig's rear connector for 'auxiliary accessories'. The two fans were mounted in an inverted plastic drawer from a spare storage cabinet. The assembly was attached to the 756-Pro II with three (3) magnets bonded with a thermal glue gun to the plastic drawer. Post-it notes were used to block the excess vent area in order for the fans to effectively do their 'cooling' job. This is shown in the picture below:

After the warm-up is complete with the fans, tune to the highest WWV frequency you can receive, and then adjust the trimmer on the rig's time base (located on the lower right side of the transceiver) for the closest 'zero beat' you can achieve when compared to the rig's side-tone. I have only done this adjustment once, and subsequently depend only on the pre-calibration procedure described on the following pages:

I turn the transceiver 'on' about 24 hours before any Frequency Measurement activities.

'Just before' an FMT, I spend about ½ hour measuring and establishing correction factors for WWV at 2.5, 5, 10 and 15 MHz. This is done as follows:

1. Rig in CW mode, "upper side" such that increasing the displayed frequency also increases the received carrier's audio tone.
2. Rec'd signal audio tone set to 600 Hz (sidetone will then also be 600 Hz).
3. Rig in "BK-IN OFF" mode, so you will <u>hear</u> the sidetone when you press the key, but the rig <u>will not</u> transmit. You can then use the sidetone as a reference to 'zero beat' the tone of the received signal.
4. Tune to the first WWV frequency. Press the key for the sidetone to heterodyne against the signal. For this example, let's say 10 MHz (10000000). Adjust the dial tuning (1 Hz resolution) until you are within 1 Hz <u>BELOW</u> zero beat (versus the sidetone). Make a note of the dial reading in Hz.
5. Count the 'nulls' rather than the peaks of the sidetone-versus-signal. (The nulls are a much sharper 'marker'). I count for 120 seconds (don't forget to start your counting time with ZERO). Let's say you counted 37 nulls during the 120 seconds.
6. Then divide 37 by 120 = 0.30833. Add this to the recorded dial reading and you will have 10000000 + 0.30833 = 10000000.30833 Hz. This means your measurement for a known 10 MHz signal was 0.30833 Hz High. Subtract 10000000.30833 from 10000000 and you get -0.30833 Hz. This is your CORRECTION FACTOR FOR 10 MHz measurements.
7. Repeat step 4, 5 and 6 for all the WWV frequencies you plan to use. Establish a CORRECTION FACTOR for each of them. They will all probably be different and will not necessarily converge toward zero at the lower frequencies. Some correction factors may have positive, rather than negative values.
8. This completes the pre-test calibration procedure. Be sure to keep a record of the CORRECTION FACTORS you measured, calculated and recorded.

Now the FMT starts:

1. Same as (4) and (5) and (6) above, find, tune to, measure and count the nulls of the signal to be measured. In this case, I count the number of nulls within 100 seconds (sometimes the test signals don't last 120 seconds!).
2. Record the dial frequency. Divide the number of nulls counted by the time the counting continued (such as 100 seconds). Add this number to the recorded dial frequency (example: Dial=3565432 + 53/100 = 3.565432.53). Record this number for further calculations after the FMT is over.
3. Find and measure (as in (1) and (2) above) the additional FMT measurements, including the counted nulls of the heterodyne.

When the FMT is over, the calculations can begin:

Here is the math used to determine the submitted FMT results, after doing both the WWV Calibration Run and the FMT Measurement(s):

Where:

A_h	=	Nearest Higher WWV Freq
A_l	=	Nearest Lower WWV Freq
C_h	=	Nearest Higher WWV Correction Factor
C_l	=	Nearest Lower WWV Correction Factor
F_m	=	(Dial+Count) Reading of FMT Signal
C_{fm}	=	Correction Factor to add, algebraically, to F_m
R_p	=	Frequency reported to FMT

Then:

$$C_{fm} = (((C_h - C_l) / (A_h - A_l)) * (F_m - A_l)) + C_l$$

$$R_p = F_m + C_{fm} = \text{Submitted Frequency Reading}$$

An interesting point about this measurement method is that it incorporates "time averaging" of the signals to be measured (the 'counting period'). I believe this helps to reduce errors caused by Doppler Effects on received signals.

73,

Phil, W1PW