Measuring Frequencies at VE3GSO

Here's a virtually zero-cost method of participating in the ARRL Frequency Measuring Test.

Dave McCarter, VE3GSO

I've been aware of the ARRL's Frequency Measuring Test for many years, but I always assumed that success required expensive test gear and a rubidium frequency standard. Imagine my surprise when I discovered that I could be a serious participant by using little more than some free software running on an out-of-date computer connected to a mid-range transceiver. I measured frequencies to just fractions of Hertz and you can, too!

The announcement in the November 2014 issue of *QST*, and also on the ARRL website (**www.arrl.org/frequency-measuring-test**) said that a Frequency Measuring Test would run on the evening of November 12 starting at 10 o'clock EST. Connie Marshall, K5CM, in Muskogee, Oklahoma, would put his well-equipped station (with its precise frequency standard) on the air and do a CW call-up for a few minutes near an announced frequency. (The exact frequency is not revealed, of course. That's for *you* to determine!) After that, he would transmit a continuous unmodulated carrier for two minutes, during which time the participants would attempt to measure the carrier frequency as accurately as possible. Connie would then transmit a sign-off before moving to the next band.

These test transmissions would appear near 7.055, 3.598, and 1.840 MHz. The *QST* article also displayed a handsome Frequency Measuring Test certificate that was available to anyone who submitted measurements within 10 Hz of any of the carrier frequencies. I thought I'd like to try for one of them!

Preparing for the Test

My Yaesu FT-950 transceiver features a stable receiver and it tunes in 10 Hz increments. It was already connected to my station computer's sound inputs via the homebrew audio transformer coupler/ground-loop isolator that I use for PSK31 and other digital modes.

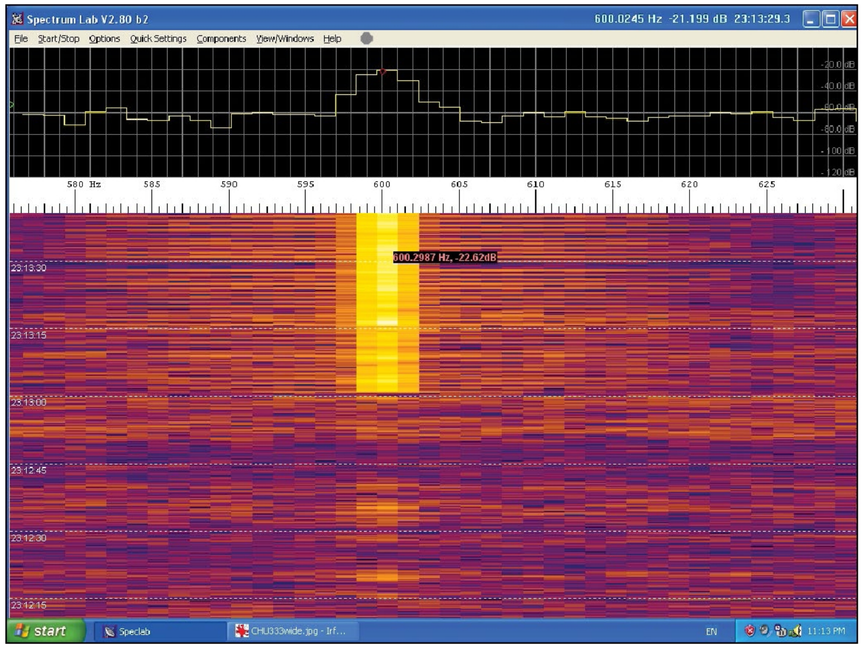

Figure 1 — Checking the *Spectrum Lab* display against WWV's highly accurate 600 Hz audio modulation tone.

I downloaded and installed the latest version of *Spectrum Lab* software, which is freely available online at **www.qsl.net/dl4yhf/spectra1.html**. *Spectrum Lab* uses the computer's sound card to perform highly accurate audio frequency measurements.

I soon determined that my sound card's analog-to-digital conversion sample rate was not as accurate as I needed it to be, but I was able to compensate. With my FT-950 in the AM mode, I simply tuned to National Institute of Standards and Technology station WWV on 10 MHz and checked the *Spectrum Lab* display against WWV's highly accurate 500 Hz, 600 Hz, and 1 kHz audio modulation tones (see Figure 1). To check the frequency of a tone on the *Spectrum Lab* waterfall, you center the crosshair cursor on the tone trace and the frequency appears beside the cursor to four decimal places. The signal level in decibels also appears.

Spectrum Lab has a calibration routine found under OPTIONS/FFT SETTINGS/AUDIO I/O called the "Sample Rate Calculator" that is specifically designed to compensate for the inaccuracy of the analog-to-digital conversion process. You enter the frequency you *expect*, eg. 1000 Hz, and the frequency that *Spectrum Lab* reports, eg. 1002.4785 Hz, and the routine calculates and sets the sample rate correction required. Remember to click APPLY so that the next time a measurement is made, it will take the error into account. When you exit *Spectrum Lab*, the software automatically saves all of your settings.

Next, I had to determine the frequency error of my FT-950 at multiple points across the HF bands. For this I switched the transceiver to the upper sideband (USB) and tuned to 1 kHz below several WWV frequencies, as well as frequencies used by the Canadian Institute for National Measurement Standards station CHU. You'll find WWV at 2.5, 5, 10, 15, 20, and

25 MHz, while CHU is at 3.330, 7.850, and 14.670 MHz.[1] Some signals are stronger than others, but all we need are the carriers, which can be detected and measured in *Spectrum Lab* even under mediocre propagation conditions.

By tuning to exactly 1 kHz below the frequency standard station, and using USB, my receiver display showed 9.999.00 when receiving WWV on 10 MHz, and I heard a 1 kHz tone. I read the tone frequency using the now-calibrated *Spectrum Lab* to an accuracy of 10 *mHz*, or 0.01 Hz. The amount by which the tone differed from the expected 1 kHz indicated the frequency tuning error of my receiver. I then tabulated and graphed my results for the frequencies needed for the Frequency Measuring Test. Here are my received frequency error results.

WWV	2.5 MHz	+ 2.78 Hz
CHU	3.33 MHz	+ 2.81 Hz
WWV	5 MHz	+ 5.38 Hz
CHU	7.85 MHz	+ 6.90 Hz
WWV	10 MHz	+ 9.54 Hz

I graphed the errors against frequency because I needed to estimate the errors in the amateur bands at 1.84, 3.55, and 7.055 MHz. This arrangement is suitable for the Frequency Measurement Test transmissions on both 80 and 40 meters because the references straddle the bands.

I knew that relying on the accuracy of the 3.33 and 2.5 MHz measurements corrections down to 1.85 MHz might be a stretch too far. In addition, it appears that the FT-950 uses a different frequency loop above 5 MHz because the graph line between 2.5 and 3.33 MHz does not line up with the 5, 7.85, and 10 MHz measurements.

Test Day

On the day of the test I warmed up the gear for several hours and rechecked the frequency errors, which were almost exactly what were measured days before. At the appointed time I was tuned to 7.054.00 MHz USB when I heard a station signing W1AW/5 about 1.5 kHz higher. I quickly re-tuned to 7.055.00 MHz to bring the tone down a bit. The carrier was sharp and clear on the *Spectrum Lab* display and I used the frequency scale expansion feature to zoom into a 50 Hz bandwidth centered on the signal.

Applying my cursor to the *Spectrum Lab* waterfall trace, I measured the audio tone at 443.161 Hz. That made the transmitted frequency 7,055,443.16 Hz, minus the all-important FT-950 error correction of 6.9 Hz. Therefore, I reported a received frequency of 7,055,436.56 Hz on the Frequency Measuring Test web page and was thrilled a few days later to learn that my measurement was off by only +0.04 Hz.

A similar story could be told about the 80 meter signal measured a few minutes later, where my result was off by a miniscule +0.02 Hz. And as I suspected, due perhaps to a lack of accurate frequency references below the 160 meter band, or an error on my part, my measurement on 160 meters was off by a still respectable –0.94 Hz.

The upshot of all this is that I successfully used equipment already in my shack to make three frequency measurements that were within 1 Hz of the official figure. It was quite an astonishing result. For future Frequency Measuring Tests, I plan to study the frequency determining circuits of the FT-950 to better understand and characterize the sources of error so that I might have more accurate error-correction factors.

The technical challenge, the adrenalin rush during the limited measurement period, the satisfaction of making use of the equipment I had on hand and used regularly, these are all in the best traditions of ham radio. As you'll read in the sidebar "April Frequency Measuring Test Format and Schedule," there is another test coming up soon. Give it a try and make measurements you never thought possible!

The author wishes to thank Tom Alldread, VA7TA, for his comments and suggestions during the writing of this article.

[1]WWV 25 MHz transmissions are experimental and may be discontinued temporarily or permanently at any time.

April Frequency Measuring Test Format and Schedule

The format for the Frequency Measuring Test (FMT) is a simple single-frequency exercise with two transmitting stations; K5CM and WA6ZTY. WA6ZTY is on the West Coast and will transmit only on 20 meters, covering the entire US with only a single skip zone. K5CM is centrally located in Oklahoma and will transmit on 40 and 80 meters. The FMT will begin on 20 meters near 14,121 kHz at 10:30 PM EDT on Wednesday evening April 8 in North America (0230 UTC, April 9, in Europe). Measure the transmitted frequency and report your results at the website provided by WA7BNM: **www.b4h.net/fmt/**. **Results must be submitted by 0300 UTC on April 11**, at which time the results will be published on the website. — *Connie Marshall, K5CM*

20 meter timeline — Signal near 14,121 kHz
WA6ZTY 10:30 Call up (5 min)
WA6ZTY 10:35 Key down (2 min)
WA6ZTY 10:37 End 20 meter transmissions and announce change to 40 meters

40 meter timeline — Signal near 7055 kHz
K5CM 10:45 Call up (5 min)
K5CM 10:50 Key down (2 min)
K5CM 10:52 End 40 meter transmissions and announce change to 80 meters

80 meter timeline — Signal near 3598 kHz
K5CM 11:00 Call up (5 min)
K5CM 11:05 Key down (2 min)
K5CM 11:07 End FMT

ARRL member Dave McCarter, VE3GSO, is a retired professor of electronics at Fanshawe College in London, Ontario. He became interested in radio and began building gear while still in public school, finally becoming an amateur in 1975 with the call sign he still holds today. Dave enjoys building QRP rigs and station accessories, is eastern net control for the Trans Canada Net (Sundays at 1800 UTC on 14.140 MHz), working DX, having friendly ragchews, and being an Elmer. He can be reached at **ve3gso@gmail.com**.

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