

# Putting Your SDR to the Test

Use your SDR receiver to participate in the ARRL Frequency Measuring Test.

## Mike Naruta, AA8K

If you'd like to see how well your software-defined radio (SDR) performs, try a Frequency Measuring Test (FMT).<sup>1</sup> FMTs are conducted in April and November by amateurs transmitting with equipment that can generate very accurate and very stable signals. You don't need special equipment to participate in an FMT. You can use a superheterodyne receiver, as described on the ARRL FMT web page, or you can put your new SDR to work. The FMT format is straightforward. The transmitting station makes a call-up for a few minutes, then transmits a steady, unmodulated carrier for a 3-minute measurement period, although some FMTs are set up to measure modulating tone frequencies or frequency shifts. The FMT announcement will describe the format. You receive the transmission, measure its frequency, submit your measurements, then compare your results with the actual transmit frequency when it is published.<sup>2</sup>

## Measurement Techniques Using Beat Frequencies

The most common technique is to receive in a DSB or SSB mode and tune for the lowest possible beat note between the receiver's beat frequency oscillator (BFO) and the FMT carrier signal. Below 100 Hz, however, because of the frequency response of the human ear and the receiver frequency response, you will not be able to hear the tone well. An alternate technique is to switch between receiving the signal above and below the carrier by a few hundred hertz so you can hear the tone clearly. Tune the receiver until you hear the same tone at each frequency and the carrier is exactly centered at the average of the two frequencies.



**Figure 1** — You can use your SDR software phase display to adjust the receiver VFO to match the FMT signal frequency. Here, the phase display of the FlexRadio Systems *PowerSDR* is shown using the author's OpenHPSDR receiver. The white figure in the middle of the display shows phase error between the received signal and the receiver VFO revolving once per hertz of frequency error. Each revolution per second is an error of one hertz.

Another zero-beat technique is to tune the receiver while watching the S-meter. As you approach the carrier frequency, the meter will move in time with the beat frequency. At the exact carrier frequency, the meter will stop changing. Unfortunately, fading (QSB) can also cause the S-meter to fluctuate, making it difficult to see the exact zero beat.

The offset method uses the receiver SSB modes. Tune to the FMT carrier so that you hear the beat frequency as a clear tone. Connect an audio frequency counter to the speaker output and measure the tone frequency. Many inexpensive digital voltmeters (DVM) include a frequency counter function, and there are numerous programs that use a computer sound card to display and measure audio signals. If your receiver is set to a USB carrier frequency of, say, 7.055100 MHz and the tone frequency is 373 Hz, the frequency of the carrier is 7.055473 MHz. In lower

sideband, subtract the audio frequency instead of adding it.

## The SDR Option

An SDR has additional options for measuring the beat frequency. If you are using *PowerSDR* or similar software, you can use the PHASE function to watch the rotation of a figure representing phase error (see Figure 1).<sup>3</sup> After adjusting the receiver frequency so that the figure stops rotating, the carrier frequency is the same as the receiver frequency. However, just like shining a strobe light on a wheel's spokes or a propeller, rotation will stop at other frequencies where the phase error is a multiple of 360 degrees as well. This is when your ears will help identify the correct frequency at zero beat. *PowerSDR* can display the received carrier RF frequency and audio tone automatically, but the frequency is that of a fast Fourier transform "bin," not the actual frequency. This is useful

for getting close, but it is not a measurement of the carrier frequency.

Two popular Amateur Radio applications for high-resolution audio tone measurement are *WSPR* by Joe Taylor, K1JT, and *Spectrum Lab* by Wolfgang Buescher, DL4YHF (see Figure 2).<sup>4,5</sup> The professional-level *Spectrum Lab* looks intimidating at first, but you don't need all of its options to measure frequency.

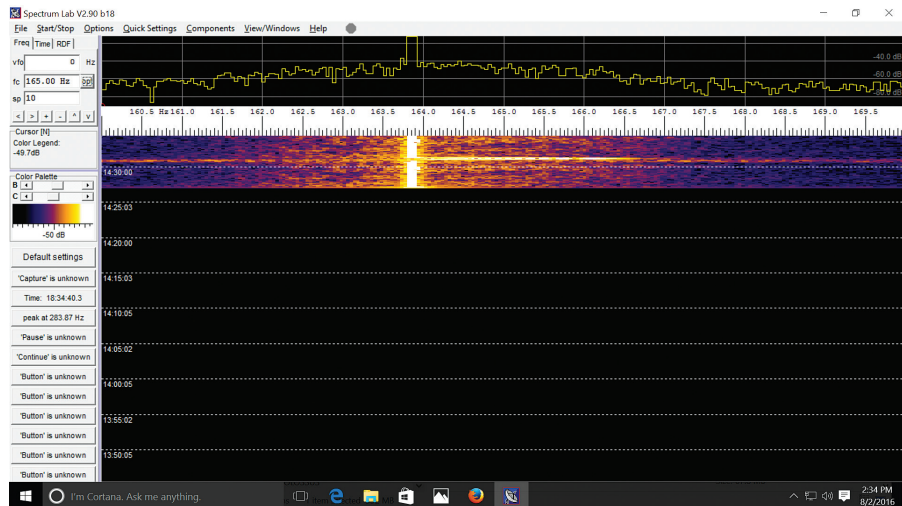
### Minimizing Receiver Error

A high-accuracy frequency standard will improve results for both an SDR and superheterodyne receiver. Some current radios come with a high-accuracy temperature-compensated crystal oscillator (TCXO) built in as a standard feature or available as an installable accessory.

Some radios also support using an external frequency standard, usually 10 MHz, such as an oven-controlled crystal oscillator. GPS-disciplined oscillators (GPSDO) have become very popular. A GPSDO uses the rubidium frequency standards aboard each GPS satellite to automatically adjust and maintain a crystal oscillator at an exact frequency. The big advantage with a GPSDO is that no other calibration is required. By using a frequency standard, you can start to close in on reading to the nearest hertz.

Another problem can be direct digital synthesis (DDS) error. Depending on your receiver design, if the frequency display indicates, say, 3.600105 MHz, it might actually be receiving on 3.60010502 MHz. DDS error can be avoided by using the output signal from an accurate signal generator to beat against the FMT signal instead of your receiver BFO. Some FMT participants use surplus laboratory-grade signal generators to make a local reference signal.

I decided to use the TAPR TADD-2 frequency divider in Figure 3.<sup>6</sup> This divider takes the 10 MHz output of the



**Figure 2** — *Spectrum Lab* display during an FMT conducted in 2013. The horizontal smearing of the signal is due to ionospheric effects. This signal is actually quite stable. The trace is vertical, rather than slanted. The audio tone is displayed in hertz on the white scale. If the SDR is tuned to 1.8449 MHz USB, the frequency of the FMT signal is  $1844900 + 163.57 = 1845063.57$  Hz.

GPSDO and generates a very accurate signal at 10 kHz, 1 kHz, or 100 Hz intervals. Using my OpenHPSDR receiver, I can measure the difference between the nearest TADD-2 signal and the FMT signal, or measure their beat frequency with the receiver BFO turned off.<sup>7</sup> With care and attention to detail, using just OpenHPSDR, GPSDO, TADD-2, and a *Windows* computer, I can compete with people who have a room full of lab equipment.

Your computer sound card sampling clock is another potential source of error. The receiver might be generating a 390 Hz tone, but your sound card might digitize that as 391 Hz. *Spectrum Lab* has a nice feature to calibrate your sound card to compensate for the sound card analog-to-digital converter (ADC) clock. I like to use WWV in AM reception for the 440, 500, and 600 Hz tones to calibrate the sound card.

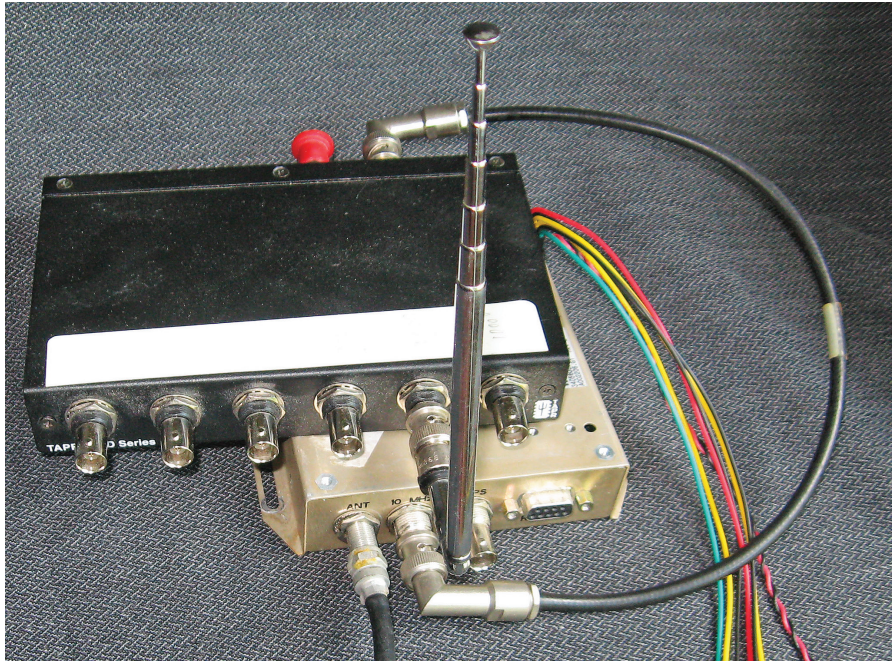
### Effect of the Ionosphere

What about pushing the envelope even further, going for a measurement to a tenth or even one-hundredth of a hertz? At sub-hertz accuracies, we run into errors caused by the ionosphere. The ionosphere is a variable-density medium with regions of both high and

low ion density, causing variations in the signal wave fronts. In addition, the ionosphere is not stationary, but turbulent in three dimensions, much like clouds churning in the lower atmosphere. At sub-hertz resolution, the FMT signal appears “fuzzy” on a waterfall display as it wanders in frequency and strength. You can observe this by tuning to WWV or CHU and watching their frequencies drift. A big part of making measurements with sub-hertz resolution is compensating for the ionosphere.

Because the ionosphere is not homogeneous, the FMT signal I measure is not the same signal that you measure. For example, during the April 2012 FMT, Connie Marshall, K5CM, in Oklahoma first transmitted on 20 meters with his beam pointed east, then transmitted with the beam pointed west. In Michigan, I measured about 0.3 Hz difference between the east and west signals, even though Connie was transmitting on the exact same frequency.

The ionosphere can be very stable, as well. Making measurements during the November 2014 FMT, which occurred during a polar vortex event in the upper atmosphere, I was able to make frequency measurements with a resolu-



**Figure 3** — A GPSDO and a frequency divider generate marker signals with an accuracy that is competitive with lab equipment. The GPSDO (bottom) is a surplus Trimble Thunderbolt and the divider is a TAPR TADD-2 with the injection whip antenna plugged into the 1 kHz output. Harmonics of the square wave are very usable through the 20-meter band. [Mike Naruta, AA8K, photo]

tion of 0.01 Hz. Variations in the ionosphere are just part of the challenge.

It's fun to compare against the other FMT participants, but remember that what they are measuring is different from you and everyone else. The data from a lot of simultaneous measurements could give a picture of just how the ionosphere is moving.

### Your Results

Depending on your equipment, you

should be able to measure frequency to within 100 Hz. If you measured to within 10 Hz — excellent! Be sure to practice before the FMT. The usual 3-minute key-down period goes by awfully fast. You can practice using WWV, CHU, or another standard frequency station. The FMT-Nuts Yahoo! group also runs practice FMT sessions.<sup>8</sup>

To report your measurements, enter your results at [www.b4h.net/fmt/](http://www.b4h.net/fmt/).



Visit <https://youtu.be/dE9np-q1EgA> to see a demonstration of frequency measurement using PowerSDR software.

Please record the frequency in hertz. The results will be published immediately following the reporting period on the same web page. Be sure to include a description of your equipment and technique and any other observations to share with others. Many thanks to the Amateur Radio volunteers who transmit and process the results, helping us upgrade our technical capabilities.

### Notes

- <sup>1</sup>For FMT techniques using transceivers, see [www.arrrl.org/frequency-measuring-test](http://www.arrrl.org/frequency-measuring-test).
- <sup>2</sup>Measurements are reported at [www.b4h.net/fmt/](http://www.b4h.net/fmt/).
- <sup>3</sup>Download PowerSDR by FlexRadio from [www.flexradio.com/amateur-products/flex-series/powersdr](http://www.flexradio.com/amateur-products/flex-series/powersdr).
- <sup>4</sup>[physics.princeton.edu/pulsar/k1jt/FMT\\_User.pdf](http://physics.princeton.edu/pulsar/k1jt/FMT_User.pdf)
- <sup>5</sup>[www.qsl.net/dl4yh/spectra1.html](http://www.qsl.net/dl4yh/spectra1.html)
- <sup>6</sup>[www.tapr.org/kits\\_tadd-2.html](http://www.tapr.org/kits_tadd-2.html)
- <sup>7</sup>[openhpsdr.org](http://openhpsdr.org)
- <sup>8</sup>[groups.yahoo.com/neo/groups/FMT-nuts/info](http://groups.yahoo.com/neo/groups/FMT-nuts/info)

Mike Naruta, AA8K, has been licensed since 1961 and has experience in broadcast engineering, satellite uplink sites, land mobile radio, avionics, IT, and language design and coding. An early RTTY experimenter with Teletype machines, he was the first ham in his county to use packet. He liked living in Liberia in 1975 and enjoyed operating as 5L6C. He joined Amateur Radio SDR in 2005 with the FlexRadio SDR-1000 and enjoys his OpenHPSDR radios. To celebrate ARRL's 100th anniversary in 2014, Mike used a Lampkin 105-B frequency meter that was designed in the 1930s for the FMT. You can reach Mike at [aa8k@arrrl.net](mailto:aa8k@arrrl.net).

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