

## Using Fldigi for the ARRL Frequency Measuring Test (FMT)

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*Held in April and November, the next Frequency Measuring Test occurs on 13 November 2020 UTC.*

### History of the FMT

The first ARRL FMT took place in [1931](#). Back then, it was required that the OOs (Official Observers) participate and meet certain standards. The OOs were hams designated to keep a watch on the ham bands for people transmitting outside the bands and they had to be capable of determining the offending transmission frequency fairly accurately. Later, as the frequency accuracy and stability of commercial ham gear improved, the FMT became more of a technical challenge for those who wished to participate. The [website](#) for the FMT includes some additional articles on techniques used in the past to make frequency measurements.

For a number of years, Connie, K5CM has been managing and making the transmissions for the FMT, and sometimes Marvin, W6OQI has also made transmissions. There is a lot of very useful info on Connie's [website](#).

### Techniques:

There are many techniques for getting good results on the FMT. Connie's website has links to some and so does the Time and Frequency Measurement section of the American Febo Enterprises [website](#).

This article is specifically about the use of [Fldigi](#) for the FMT. Currently, *Fldigi* by Dave, W1HKJ has a **Frequency Analysis Mode** that can measure a signal's frequency to three decimal places; i.e. to 1 mHz (millihertz). Recently, a new **Frequency Measuring Test Mode** has been added that will replace the **Frequency Analysis Mode**. It still measures an unknown frequency to three decimal places, but it also can use a reference frequency to correct the unknown calculation for inaccuracies of the receiver.

### Equipment

Very little equipment is necessary for participation in the FMT. In fact, one can use a PC connected by internet to an on-line SDR (software-defined radio). There are a number of GPS stabilized SDRs called Kiwi SDRs that can be accessed at [kiwisdr.com](http://kiwisdr.com). Use a hardware cable or a virtual cable to connect the audio from the SDR to the input of *Fldigi*. Calibration will be required.

While older rigs can be used, *Fldigi* works best with a rig that can be controlled by a serial or USB connection from the PC to set the VFO with 1 Hz resolution. Some rigs display frequency to 1 Hz. Others only display to 10 Hz but can be set by the PC to 1 Hz. Most rigs dating from about 1995 and later will work well. *Fldigi* needs to know the frequency that the radio *thinks* it is tuned to or the frequency that you think it is tuned to.

The new FMT modem works best with a reference signal injected along with the FMT transmitted signal — the FMT's unknown signal. The reference signal must have some accurately known frequency that can be set near the unknown frequency (within 1 kHz or so). The reference can be a signal generator stabilized by a GPSDO (GPS Disciplined Oscillator) or a GPSDO that can be easily set to output a useful frequency. An example of the latter is the Leo Bodnar GPSDO single-output, [Mini Precision GPS Reference Clock](#). Using *Fldigi*'s new FMT modem without a reference can still provide good results but requires careful calibration.

## Getting Started

First, download *Fldigi* for your PC. It is available for Windows, Mac OSX, and Linux. For Windows, download and run *setup.exe*. Then download the *Fldigi* Help file. If you haven't already, join one of the user groups: for Windows that is [groups.io/g/winfldigi](http://groups.io/g/winfldigi) and for Linux and OSX, [groups.io/g/linuxham](http://groups.io/g/linuxham).

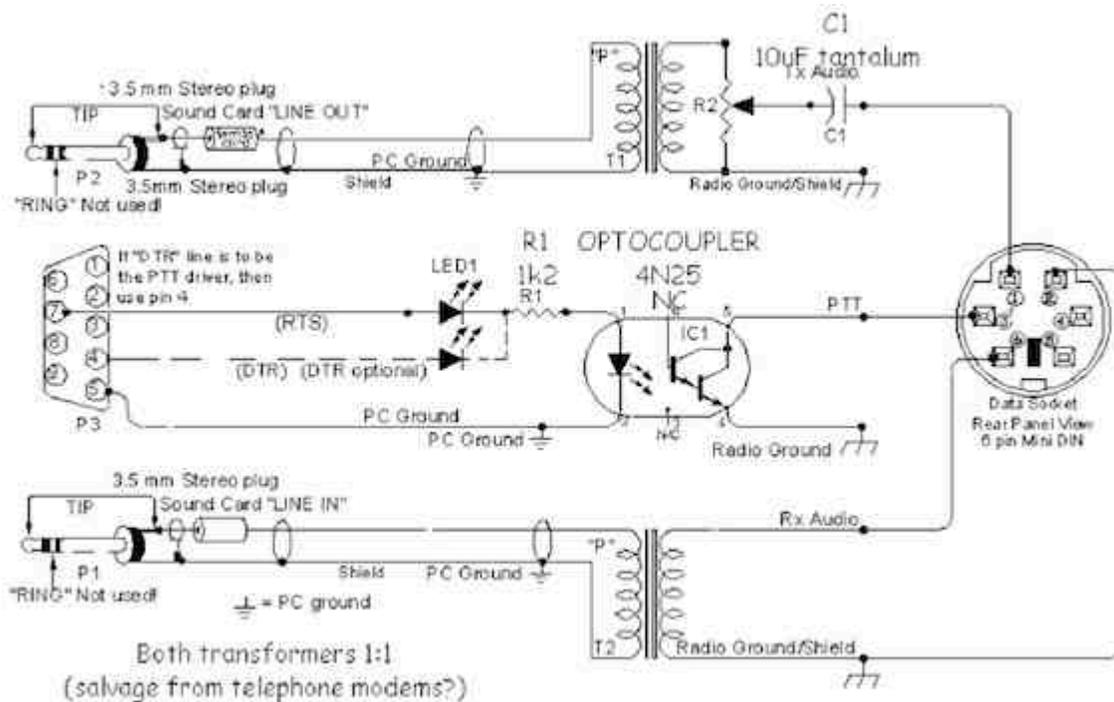
Install both *Fldigi* and *Flrig*. For Windows, you will have to give permission to install a program from an unknown publisher and provide the admin password. The first time you run the program, you will have to also provide the admin password to allow access.

There are several ways to connect the rig to *Fldigi*. The recommended method is to use *Flrig*. (There is a help file for *Flrig* on the site — get that, too!) The connection can also be made using *hamlib* or *RigCat*. *RigCat* uses an XML file specific to your rig that can be downloaded from the *Fldigi* website.

## Connecting the Rig

The next step is to make the physical connection between the rig and PC for rig control using the CAT (Computer Aided Transceiver) interface. If the rig has an RS-232 connection and your PC does not have any physical COM ports, you will need an RS-232 to USB adapter. Make sure you use an adapter with the FTDI chip set. (Adapters based on the Prolific chip are known to have compatibility issues with ham software.). Newer rigs just need a USB cable and several have both a USB Audio Codec and CAT combined in the USB connection. The *Flrig* help file and the user groups have a wealth of information on getting the rig working with *Flrig*.

If you need to provide separate audio connections from rig to PC you might be able to get away with no interface, just shielded cables from your PC sound card MIC IN or LINE IN to the rig's data interface audio output and the PC sound card PHONES OUT to the data audio input. (Be sure to use good quality shielded cables and connect the shield at both ends.) That isn't ideal as you might experience noise problems, but there is no harm in trying. If you prefer to use a standalone interface, the most common is [Signalink by Tigertronics](#). There are cheaper alternatives such as building your own. The standard circuit published by PEØSAT follows:



You may not need the PTT part of the circuit as most rigs support PTT by computer control through the USB or serial connection. The source of audio and PTT may cause some confusion: Some rigs, if keyed by PTT in the AUX or DATA connector take the audio input only from the AUX connector, and not from the mic connector.

### Configure Rig Control

If you are going to use *Flrig* (recommended), with the rig on and connected to the PC run *Flrig* and use the help file to configure it for your rig. Always have the rig on when starting *Flrig* and shut down *Flrig* before turning off the rig. (This avoids communication failure errors when the rig fails to respond to a command.)

If PTT turns on the transmitter but the rig stays in transmit when PTT is released, you may have RF being picked up by the control cables. That can usually be solved by putting type #31 ferrite cores on the cables to block the RF common-mode current. See K9YC's [online tutorial](#) on ferrites and RFI for more information on using ferrites.

### Using *Fldigi* for an FMT

Once you have *Fldigi* and *Flrig* running and talking to each other, [configure the soundcard](#). Always perform a **Save** after changing the configuration.

Next, calibrate the computer (or rig) sound card. Select **WWV Op Mode** and tune the rig to a WWV station in AM mode. Follow the instructions here: [www.w1hkj.com/FldigiHelp/digiscope\\_display\\_wwv\\_mode.html](http://www.w1hkj.com/FldigiHelp/digiscope_display_wwv_mode.html).

Once the soundcard is calibrated, select **Frequency Measurement Op Mode** and browse to [www.w1hkj.com/FldigiHelp/fmt\\_page.html](http://www.w1hkj.com/FldigiHelp/fmt_page.html).

As mentioned earlier, the FMT modem of *Fldigi* can measure the frequency of two closely spaced signals, one being the known stable reference and the other the unknown to be measured. The reference is assumed to be accurate, so drift and inaccuracies in the radio can be compensated for.

If there is no reference available, receiver drift and accuracy need to be determined by comparing the results of a run with a known frequency such as CHU or WWV.

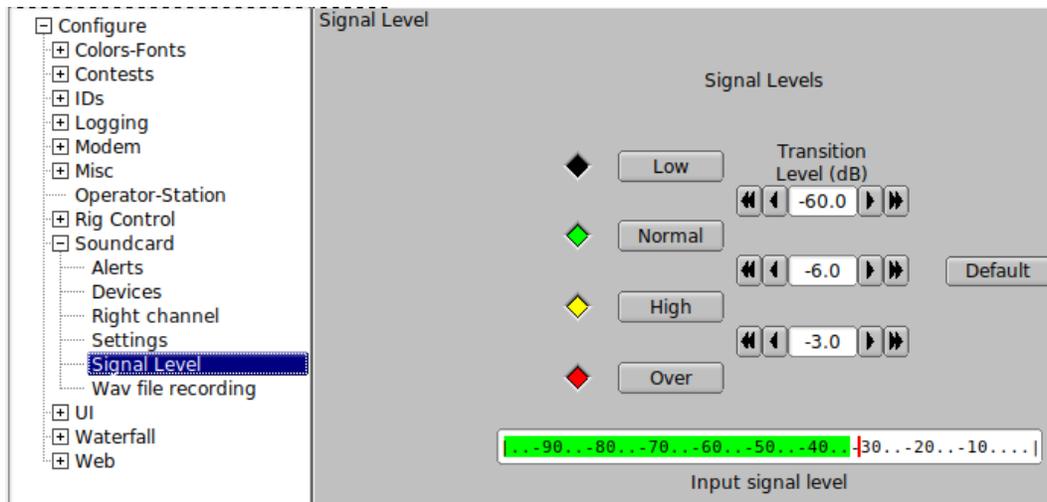
### Configure the FMT Modem

Carefully read through the FMT usage page. Initially, use the default settings except for any color changes you wish to make. You may prefer to set the **DFT Estimator Data Filter** to 0 to make the tracking more responsive. **Audio Sync to Data Record** is also a very useful feature: After recording an FMT, you can replay the audio file through *Fldigi* with different configurations to see what happens. Note that the CSV (comma-separated values) file created during a run is intended to be opened by a spreadsheet program such as *Excel* or *Libre Calc*.

### Measure Frequency Without Using a Reference

To measure frequency without using a reference, tune the rig on USB to some frequency, say 1000 Hz below the carrier to be measured. i.e. For 5.000 MHz WWV, tune the rig to 4.999 MHz. You should hear a 1000 Hz tone. Assuming the audio is properly connected from the rig to the PC, you should see a trace on the waterfall at the 1000 Hz mark.

In the **Soundcard** configuration, click on **Signal Level** to get the following window:



Using either the rig audio input control or PC audio output control set the audio level of a reference or unknown signal somewhere between -60 dB and -6 dB. Near -30 dB would be good.

With the mouse pointer on the trace at 1000 Hz on the waterfall, press Shift-Left-Click. The **Unk** (Unknown) vertical cursors should appear over the trace. You can fine tune the cursor position using the **Unk** frequency control:



- o **Outer buttons:** +/- 10. Hertz
- o **Middle buttons:** +/- 1.0 Hertz
- o **Inner buttons:** +/- 0.1 Hertz

When the cursor is lined up with the trace +/- 1 Hz or so, click on the **Unk** button to start tracking the signal. The indicator in the **Unk** button should turn yellow and the frequency and dBV amplitude value of the signal should appear in the windows. Once tracking begins, the trace should appear in the graph. Note that you won't see anything if the error (the difference between the actual frequency and the cursor frequency) is greater than the range of the graph set by the **Scale** button. If, for some reason, tracking is lost, try clicking on the **Reset** button.

Before starting to record the data, check that **Interval** and **T-scale** are set the way you want. **Interval** sets the time between records in the CSV file and **T-scale** sets the total time on the graph. **T-scale** has no effect on the recorded data.



When you click on **Record**, the button's indicator will turn yellow and when data is being recorded, the indicator to the left of the button will turn brown. If you have enabled **Audio Sync to Data Record** in the configuration, the audio will be recorded to a WAV file. Clicking the **Record** button again will stop the recording and close both the CSV and WAV files.

The CSV file includes the equations for calculating average frequency. When opened with a spreadsheet, average frequency will be shown in a cell at the top right as shown below.

P	Q
W1HKJ	2020.08.24.18.41.12
Average:	10000000.0944625
Std Dev:	0.025915964725424

### Measure Frequency Using a Reference

The reference signal needs to be coupled to the antenna so the receiver sees the unknown signal and the reference with somewhat similar signal strengths. The coupling method could be capacitive or perhaps as simple as connecting the reference generator to a loop of wire near the receiver. Set the reference frequency to several hundred Hz below or above that of the unknown signal. When you have a trace on the waterfall from the reference, CTRL-click on the trace to

put the **Ref** cursor on the trace and fine tune as with the unknown. Click on the **Ref** button to start tracking.

Once tracking has started, you can use the dBV readings on the FMT modem to adjust the reference signal strength to be within 10 to 20 dB of the unknown. Click on **Record** to start the data recording and click on **Record** again to stop the recording and close the files.

## Data Analysis

When the resulting CSV file is loaded into a spreadsheet, the calculated average frequency will be corrected using the data from the reference assuming the reference frequency is accurate.

First, delete data rows that were recorded before or after a "good" signal was received. For example, you might start a recording before key down during an FMT, then stop the recording after the end of key down. The FMT modem will take a few seconds for the tracking to stabilize once the signal appears, and that bad data can be seen by charting **Unk Err** (Unknown Error) against time. When only good data is left, you can use the **Average** function for further calculations.

If you are not using a reference, the first measurements you make should be on CHU or WWV in order to calculate your receiver's frequency error and drift. These measurements should be made after the rig has warmed up for several hours. The best time of day to make these calibration measurements seems to be an hour or so after the midpoint between you and the transmitting station is at local noon. That seems to be when the ionosphere is the most stable and Doppler shift has the least effect on the received frequency.

Make measurements on the different frequencies available with CHU (3330 kHz, 7850 kHz, and 14670 kHz) and WWV (2.5, 5.0, 10.0, 15.0, and 20.0 MHz). Make a chart of **Unk Err** vs frequency to give you an idea of what error your rig has at any frequency. For most rigs, the chart will be linear. Then, when you measure an unknown frequency, you can apply the calculated receive error from the chart to get a more accurate estimate of the unknown frequency.

If you do a long run measuring CHU or WWV, you can get an idea of any drift your receiver may have. You might have to factor drift into your "guess-timations" of unknown frequencies.

If you are using a reference, measurements of CHU and WWV will give you an idea of frequency offsets in your measurements as there likely will be some.

## Doing the ARRL FMT

Since we know the approximate frequencies for the FMT, you can set up in advance. For example, the 40-meter frequency will be near 7064 kHz, so, set the receiver to 7063 USB. Set the reference signal to something like 7063.5 kHz and put the **Ref** cursor on its trace. Start tracking on the reference. Receiver AGC should be OFF to prevent the gain being affected by the reference or any nearby signals.

It is a good idea to ensure that **Sync to Data Record** is enabled so you will have an audio recording to play back through *Fldigi* if there is some problem during the FMT transmission.

Shortly before the beginning of the FMT, do a short run on a CHU or WWV frequency closest to the FMT frequency. Do the same after the FMT. You can use these runs to estimate the effect of Doppler shift at that time. There is enough time between the 40 and 80-meter FMTs to do these calibration runs and still be set up for the next FMT run.

The FMT starts with three minutes of CW call up giving you a chance to find the frequency and get the **Unk** cursor on the trace. Start tracking as soon as you have the **Unk** frequency set. Click on **Record** before the key down time. If the **Unk** loses tracking, try clicking on **Reset**.

Then November 2020 FMT features a new wrinkle in that the call up frequency will be slightly different (by less than 10 Hz) from the key down frequency. *Fldigi* is quite good at finding the different frequency and locking onto it, but a **Reset** might be necessary.

### **After the FMT**

Load each CSV file into a spreadsheet and delete the records that were outside the time of key down and stable tracking. You may also have calibration files made from CHU or WWV just before and just after each FMT run. Chart the **Unk Err** from those files and look at the **Average** to see if there is a consistent offset. If so, you might want to add that offset to your average values for the FMTs. You will notice that at the time of day of the FMTs, 02:00 to 02:30, the ionosphere is quite unstable leading to a significant variation in your measured frequencies over time. Looking at the charts of your calibration runs and FMT runs, you make a guess at what Doppler shift is doing to the frequency during the FMT.

At that time in the evening, the ionosphere is becoming less dense, causing the effective path length between you and K5CM to be increasing with time. This causes an overall reduction in apparent or measured frequency. Using your calibration runs, you might be able to estimate what that frequency shift might be and apply that to your final measurement. Good luck with that!

Finally, submit your results on [fmt.arrl.org](http://fmt.arrl.org) and on [K5CM's website](#). Above all, have fun!