Using the SDRPlay SDR Receivers with an External Frequency Reference

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1. Introduction

The SDRPlay software define radio (SDR) receivers (figure 1) have a wide frequency range and are useful in many radio astronomy applications. Most of the SDRPlay receivers can accept an external reference frequency source to improve their frequency accuracy and stability for applications that require it. This article describes using an external frequency reference disciplined by the *Global Navigation Satellite Systems* (GNSS) with the SDRPlay RSP2/RSP2Pro, RSPduo and RSPdx.

Figure 1 ~ The RSPduo (left) and RSPdx (right) SDR receivers cover the same frequency range – 1 kHz to 2 GHz. The RSPduo has two internal tuners and the RSPdx is a redesigned RSP2Pro with additional low frequency filters. The RSPdx is slightly larger at 4.4 L x 3.7 W x 1.4 H in (113 x 94 x 35 mm). Both receivers have a connector on the back panel for an external reference frequency source. Not shown are the RSP2 and RSP2Pro. Images source: SDRPlay

A couple examples of applications that require accurate frequency are the detection of pulsars and the Doppler shift measurements of the radio emissions from neutral hydrogen clouds in interstellar space (figure 2). Only the hydrogen emissions are briefly described. Neutral atomic hydrogen (designated by the letter and Roman numeral HI) are *spectral line* emissions that occur near 1420 MHz (21.1 cm wavelength). The received emissions are Doppler shifted because the clouds usually are moving with respect to the receiver on Earth.

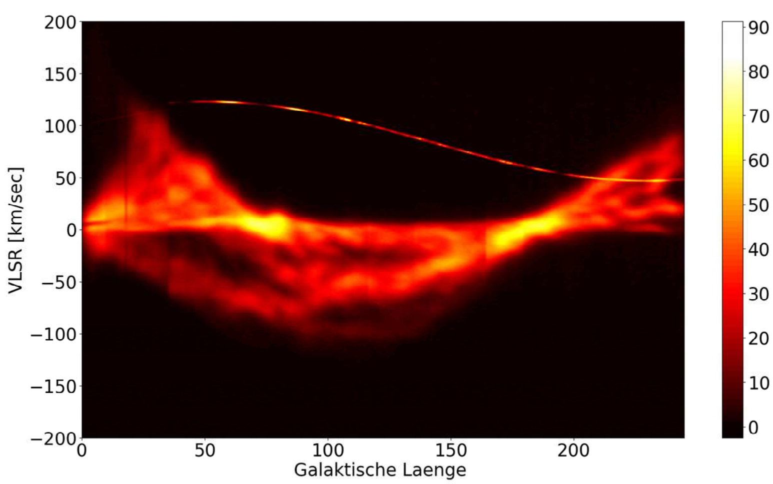

Figure 2 ~ Neutral hydrogen velocities in the Milky Way galactic plane with respect to the local standard of rest (VLSR, left scale).Relative brightness is shown by color. Velocities are based on Doppler shift measurements at 1420 MHz with the 3 m reflector antenna at Astropeiler Stockert (but not with an SDRPlay receiver). Spectra scans in 0.5° increments from 0 to 240° galactic longitude (horizontal scale) were assembled to produce the plot. The spurious line through almost all longitudes is due to fixed frequency RFI, which appears at different velocities due to local standard of rest correction. Image source: Astropeiler Stockert, used with permission

Higher receiver frequency accuracy and stability allow higher accuracy and less uncertainty in the Doppler shift measurements and the velocities derived from them. The equivalent velocity error v_{Error} (m s^{-1}) due to receiver frequency error Δf_{Error} (Hz) is calculated from

$$v_{Error} = \frac{\Delta f_{Error} \cdot c}{f_0} \tag{1}$$

where *c* is the speed of light in space ($299.8 \cdot 10^6$ m s^{-1}) and f_0 is the rest frequency of neutral hydrogen (1420 405 752 Hz). If the receiver frequency error is, say, +71 kHz, the equivalent velocity error is 15 km s^{-1} toward Earth. If it is desired to keep velocity measurement errors due to frequency errors < 1 km s^{-1}, then the frequency error at 1420 MHz must be < 4738 Hz, or < 3.3 Hz for every 1 MHz of oscillator frequency used in the receiver. An ordinary free-running crystal oscillator has a typical frequency error of 50 to 100 Hz for every 1 MHz of operating frequency at room temperature.

Section 2 of this article briefly discusses frequency reference sources based on GNSS, section 3 describes a specific high-accuracy source, the *mini-GPS Reference Clock* by Leo Bodnar Electronics, and section 4 describes the application of this source to certain SDRPlay receivers, namely the RSP2, RSP2Pro, RSPduo and RSPdx. The RSP1A does not have an external reference input. Section 5 lists the procedures for setting up the external frequency source and the SDRPlay receivers, and section 6 has weblinks and references.

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2. GPS Disciplined Oscillators

Significant improvements in frequency accuracy are possible by combining a GNSS receiver with an oven-controlled crystal oscillator (OCXO) or temperature compensated crystal oscillator (TCXO). Of the several GNSS presently in service, the Global Positioning System, or GPS, is the most familiar. Frequency sources that use GNSS are commonly called *GPS-Disciplined Oscillators*, or GPSDO. Other names are GPS reference clock and GPS reference frequency source. The acronyms GNSS and GPS are used interchangeably in this document.

One important characteristic of frequency references derived from GNSS signals is their very high long-term frequency accuracy, on the order of 1 part in 10^{12}, which is equivalent to 1.42 mHz at 1420 MHz. However, a GNSS receiver alone provides only long-term accuracy; its short-term stability is compromised by the nature of radio propagation through Earth's ionosphere and atmosphere. Therefore, a high quality, low jitter (or, equivalently, low phase noise) oscillator is used in conjunction with the GNSS receiver to provide a combined frequency source that has both high long-term accuracy and high short-term stability. With an inexpensive TCXO, it is possible to achieve a short-term frequency error of 5 parts in 10^8, equivalent to around 700 Hz error at 1420 MHz.

The foregoing discussed frequency accuracy in terms of frequency error in Hz. A more universal measure is the accuracy measured in parts per million, ppm. The value in ppm is found by dividing the frequency error by the ideal frequency f_0, both in Hz, and multiplying by 1 million, as in

$$\Delta f_{Error}(ppm) = \frac{\Delta f_{Error}(Hz) \cdot 10^6}{f_0(Hz)} = \frac{\left[f_0(Hz) - f_{Meas}(Hz)\right] \cdot 10^6}{f_0(Hz)} \tag{2}$$

For example, an error of 50 Hz at 1 MHz is 50 ppm and an error of 4738 Hz at 1420 MHz is 3.3 ppm. When the frequency error is very low, it may be given in parts per billion, ppb, or even parts per trillion, ppt. An error of 700 Hz at 1420 MHz is 493 ppb and an error of 1.42 mHz at 1420 MHz is 1 ppt.

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3. Mini-GPS Reference Clock

The very compact mini-GPS Reference Clock (figure 3) uses a 72-channel ublox M8030 receiver and handles concurrent reception from up to three GNSS – GPS, GLONAS and Galileo by default. The receiver is capable of receiving the Beidou GNSS but is not setup for it. The mini-GPS Reference Clock provides good performance and costs about 112 USD (October 2020). A more expensive and slightly larger unit with two outputs also is available from Leo Bodnar Electronics.

Figure 3 ~ Leo Bodnar Mini-GPS Reference Clock shown approximately full size. Dimensions are 2.1 L x 1.6 W x 0.7 H in (53 x 40 x 17 mm). The GPS antenna is connected through the SMA-F connector on the left; the output is on the other end and also uses an SMA-F connector. A mini-USB connector next to the GPS antenna connector is used for power from a 5 Vdc source. The unit may be connected to a PC USB port to set the frequency and output level and check satellite status. Image source: www.leobodnar.com

I acquired the mini-GPS Reference Clock from SDR-Kits {SDR-Kits}, but it also may be ordered from the manufacturer {mini-GPS} and other vendors in the USA and Europe. Only a little documentation is available for the unit – mine arrived with a small sheet of paper printed on both sides with some technical information, application examples, and a screenshot of the software configuration tool that is available for the unit. Setup is easy; detailed instructions are not necessary but they are given in section 5 anyway.

The Leo Bodnar Electronics unit is one of several inexpensive frequency sources currently available that use GNSS signals. However, many typically have only a 10 MHz or a pulse-per-second (PPS) output and will not work with the SDRPlay receivers. The mini-GPS Reference Clock is more flexible and produces a programmable output that can be set to almost any integer frequency between 400 Hz and 810 MHz (the frequency range is according to the manufacturer's data). For the SDRPlay receivers, the reference frequency must be set to 24.000 000 MHz.

The mini-GPS Reference Clock uses a mini-USB-B connector for power and setup. The settings are non-volatile so the unit may be disconnected from the PC and then repowered from any good-quality power source capable of supplying 250 mA at 5 Vdc. However, if it is desired to continuously monitor the satellites received by the unit, it must be left connected to the PC.

The GPS antenna input and reference frequency output connectors are type SMA-female. An LED near the output connector indicates satellite tracking status (figure 4). It can be set to solid or blink when tracking satellites but the blink setting does not survive power-off. When power is first applied and before satellites are tracked, the LED blinks about once every 2 seconds. When tracking, and if the Blink function is set, the blinking rate increases and appears to be synchronized with the receiver's PPS output. If the Blink function is not set, the LED turns solid to indicate satellite tracking.

The output frequency is set in Hz but not every integer value between 400 Hz and 810 MHz is possible. When the frequency is changed with the configuration tool, the internal controller calculates the frequency synthesizer settings. There is a short delay between entering the value and it being set. If the exact frequency is not possible, the nearest available value is displayed. The frequencies I tried that were not possible as entered were displayed within a small fraction of a Hz. Unfortunately, there is no easy way to determine in advance if a given output frequency is possible without actually trying it on a live unit. It is possible to manually calculate the frequency synthesizer settings and then enter them with the configuration tool but that is beyond the scope of this article. Alternately, the manufacturer may be asked via email about specific frequency settings (I found their responses to my inquiries to be quite timely).

Figure 4 ~ Mini-GPS Reference Clock front panel showing the output connector and unlabeled status LED to the left of the connector. Image source: www.leobodnar.com

The fact that some specific frequency settings are impossible may appear to limit the mini-GPS Reference Clock's utility as a *universal* frequency source. However, even though the resulting frequency may not be set exactly at the desired value, the error is a fraction of a Hz and probably sufficient for most amateur radio astronomy applications. The 24 MHz setting for the SDRPlay receivers is accepted and displayed as 24 000 000 (without the spaces).

The mini-GPS Reference Clock documentation mentions that if the GNSS satellites are not available – for example, due to antenna failure or poor antenna location – the unit uses a *holdover* mode in which the internal frequency control (digital phase-locked loop) maintains the best estimated output frequency based on stored historical data. When satellite lock is later attained, the output is automatically resynchronized. Entry to and exit from holdover mode are claimed to be *glitch-less*; I found this to be true in terms of the way the mini-GPS Reference Clock works with the SDRPlay receivers.

In addition to the output frequency, the output power level may be adjusted with the supplied software configuration tool. According to the documentation four discrete levels are possible: +6.4, +9.0, +9.9 and +10.3 dBm; these are given at 10 MHz. The configuration tool has a drop-down list for the output setting but instead of showing them as power levels in dBm, the list shows *Output drive strength* in mA. The settings are 8, 16, 24 and 32 mA, and these correspond to the four power levels. The output apparently is produced by CMOS technology with 3.3 V_{pk} level into a 50 ohm load and is adjusted downward from there.

The base of the output waveform is 0 V (ground); the waveform is not symmetrical around 0 V but it has a 50% duty cycle (figure 5). Therefore, the output has a dc voltage bias equal to one-half the peak output voltage. Since the output powers and *drive strengths* are provided only for a frequency of 10 MHz, some experimentation may be needed for loads other than 50 ohms and frequencies other than 10 MHz. Also, some devices may not be compatible with a frequency source that has dc bias, including the RSP2 and RSP2Pro and some devices with transformer coupled reference inputs, so it may be necessary to provide ac coupling (a series capacitor). There are other specific requirements for the SDRPlay receivers that are discussed in the next section.

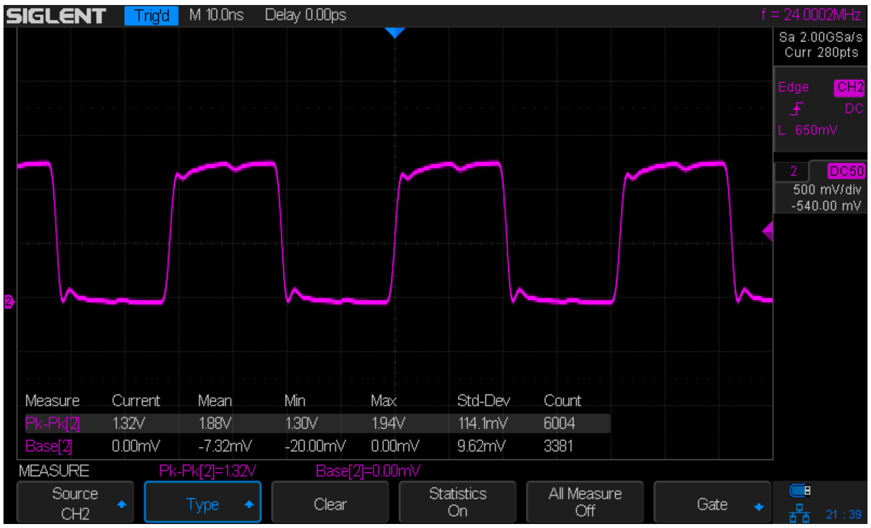

Figure 5 ~ Oscilloscope screenshot of the output with *Output drive strength* set to 8 mA. The scope channel input is configured for 50 ohm load. Note the triangular marker on the left edge at 0 V; the marker on the right edge shows the trigger level. The zero-to-peak voltage is 1.32 V and is shown in the statistics table near the bottom. The frequency is 24 MHz. For reference, the unloaded (1 Mohm) zero-to-peak output voltage is about 3.12 Vpk.

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4. Application of the External Reference Source to the SDRPlay Receivers

The SDRPlay receiver models RSP2, RSP2Pro, RSPduo and RSPdx have good frequency accuracy out-of-the-box, but the frequency drifts a little with temperature, and drift due to crystal aging is impossible to avoid. The frequency accuracy at a particular temperature may be improved by calibrating the receiver's internal oscillator with an accurate frequency source, but that calibration is good only at that temperature. Calibration is discussed later in this section.

To improve operation where the temperature varies (most installations), the above-mentioned SDRPlay receivers may be connected to a stable external frequency reference source. Each SDRPlay receiver has a reference clock input and the RSP2/RSP2Pro and RSPduo also have a reference clock output so that two or more of them may be daisy-chained in a master-slave setup (figure 6).

The SDRPlay receivers cannot be arbitrarily connected to or disconnected from an external frequency reference source while in operation (*hot-swapped*). For example, the RSP2 and RSP2Pro will lock-up and both the software and hardware will have to be reset. The later models, RSPduo and RSPdx, are not as sensitive. A specific procedure, described in section 5, is recommended to prevent receiver problems and is especially important with the RSP2 and RSP2Pro.

The reference input and output connections on the SDRPlay receivers use type MCX-F connectors whereas the mini-GPS Reference Clock output uses a type SMA-F connector. The mated MCX connectors are small and are held together by a detent mechanism. The connectors can be easily pulled apart, so interruption of the reference frequency signal is possible by simply moving the receiver around.

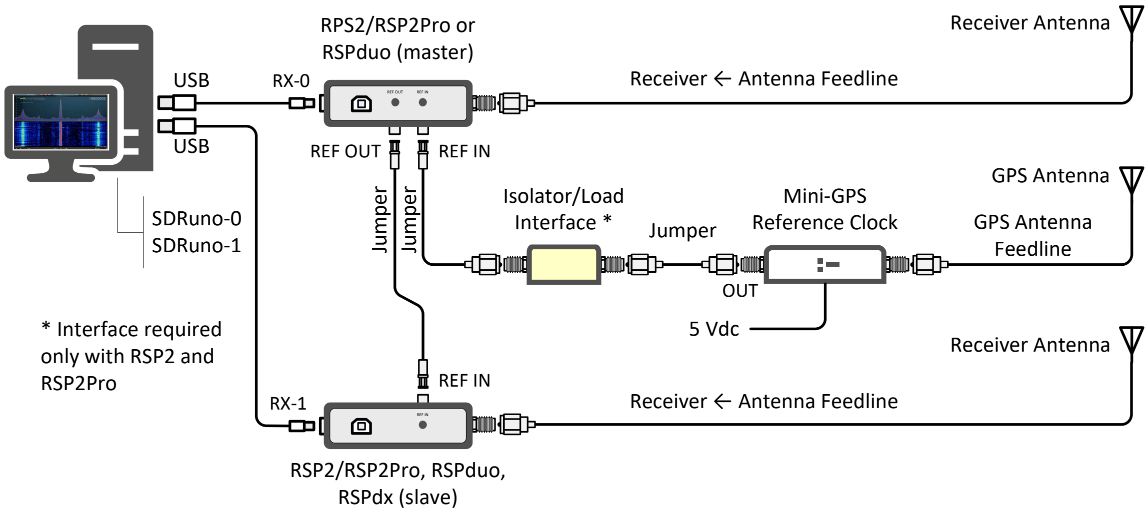

Figure 6 ~ Block diagram showing the reference clock with two receivers connected as master and slave. The receivers are powered through their USB connections to the PC. The mini-GPS Reference Clock may be powered by a PC USB port or a separate 5 Vdc power supply. Image © 2020 W. Reeve

According to SDRPlay, an interface circuit should be used with the RSP2 and RSP2Pro to prevent any dc bias or offset on the frequency source waveform from being applied to the receiver reference clock input; furthermore, the RSP2 and RSP2Pro require an external dc return path to ground for the reference clock input. I contacted SDRPlay to clarify the requirements, and table 1 summarizes their responses and reference clock information for the RSP2/RSP2Pro, RSPduo and RSPdx.

If an interface circuit is required, it is very simple, consisting only of a resistor and capacitor (figure 7). I built the interface in a small cast-aluminum box. This interface is only specifically needed with the RSP2 and RSP2Pro.

Table 1 ~ SDRPlay receiver reference input information

Characteristic	**RSP2/RSP2Pro**	**RSPduo**	**RSPdx**
Reference Input and Output	Both	Both	REF IN only
Isolator/load circuit req'd between the reference source and the REF INPUT	Yes	No	No
Disturbance on REF INPUT in operation	Lock-up	May or may not lock-up	May or may not lock-up
Maximum dc bias applied to REF INPUT	0 Vdc (ac coupling)	+1.65 Vdc	+1.65 Vdc
Signal voltage range on REF INPUT	1 – 2 $V_{pk\text{-}pk}$	1 – 3.3 $V_{pk\text{-}pk}$	1 – 3.3 $V_{pk\text{-}pk}$

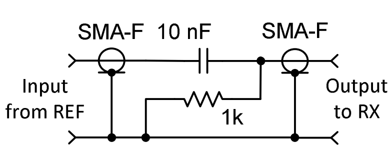

Figure 7 ~ Isolator/load interface schematic (left) for the SDRPlay receivers built into a small Pomona Electronics aluminum box. The inside view of the interface front panel (middle) shows its simplicity. The box dimensions are 1.50 L x 1.13 W x 0.88 H in (38 x 29 x 22 mm). Images © 2020 W. Reeve

There are no hardware or software indications that the receiver is actually using the external reference source. The SDRPlay documentation says the acquisition of the external reference frequency signal is a hardware-only function with automatic switching to the source when it is present; there is no linkage to the software.

As noted in the above table, any problem or disturbance with the reference clock input to the RSP2/RSP2Pro, for example, momentary loss of the output from the reference source, will stall both the receiver and the SDRuno software. If so, then both must be shut down and restarted. I also encountered this problem on the RSPduo when removing the reference input connection while in operation. The RSPdx handled loss of signal – by cycling the power on the reference frequency source – without locking up but I did see a few Hz hit on the displayed signal while receiving WWVB on 60 kHz. Apparently, it is the physical connection or disconnection of the frequency reference and not the presence or absence of a signal that locks up the receiver.

When the receiver locks up, it is no longer recognized by the PC. Normally, this would require unplugging and then plugging the receiver USB cable into the PC USB port, a serious problem for a remote receiver. However, I found that going to *Device Driver – Sound, video and game controllers*, Disabling the SDRPlay (RSPxx) entry and then Enabling it after a short delay, the receiver and software may run okay. This worked for me with the RSP2/RSP2Pro but not the RSPduo and may not work every time.

Disabling and then enabling the receiver, if it works, is useful for remote observatories where the receiver cannot be physically accessed. An alternative is to remotely reboot the PC, a risky proposition with the Windows operating system. In these situations, a remote desktop software application may be used such as TeamViewer, Microsoft Remote Desktop Connection (RDC), or Chrome Remote Desktop (CRD), to remotely access the Device Manager.

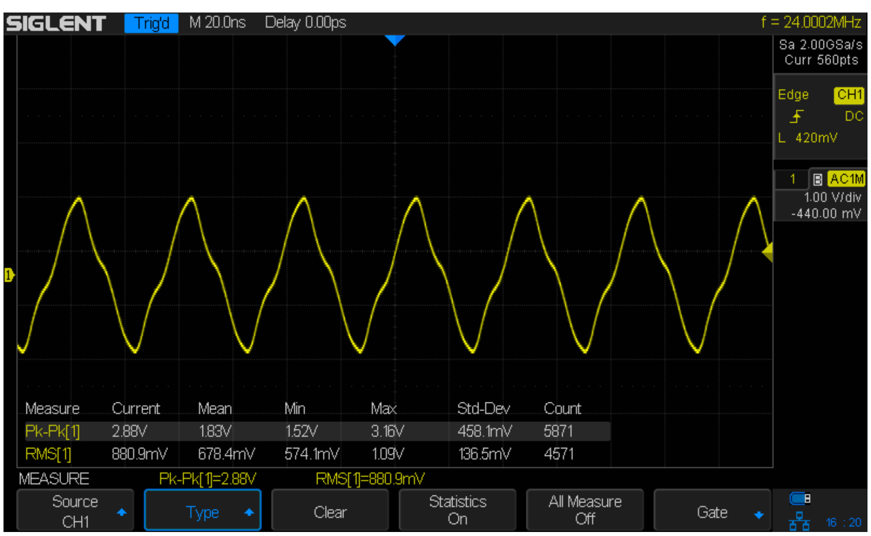

Figure 8 ~ Measured waveform on the load side of the interface with the mini-GPS Reference Clock connected through the interface to the RSPduo receiver. Note that because of the coupling capacitor, the waveform is symmetrical about zero volts. The peak-to-peak voltage is 2.88 V, and the frequency is 24 MHz.

The reference frequency output loading by the receiver's REF IN circuitry depends on the receiver model. The RSP2Pro shows a different waveform voltage when under load than the RSPduo, probably due to different input circuits. An oscilloscope screenshot shows the waveform measured when the mini-GPS Reference Clock is connected to the RSPduo through the interface described above (figure 8). I noted that, under these conditions, the measured output voltage did not change with different settings of the *Output drive strength* in the reference clock. Note that the RSPduo does not require an interface, but I did not measure the waveform without it.

Frequency calibration is another aspect of system operation. For best accuracy, frequency calibration should be performed at the frequency of interest and with the frequency source that is to be used in the application. For example, if the receiver is to be used only with its internal oscillator, the frequency calibration would be performed in that configuration. On the other hand, if the receiver is used with an external reference, such as the mini-GPS Reference Clock, calibration would be performed with the receiver connected to it. If the configuration is changed afterwards, recalibration would be necessary. In principle, the receiver frequency would not need calibration when the receiver is locked to an external precision reference frequency, but I found a small correction was necessary to center a precision 15 MHz carrier (WWVH) on the RSP2Pro and RSPduo spectrum displays.

Both manual and automated frequency calibration methods are provided in the SDRuno software (figure 9). The manual method is accessed through the *Main* window panel, *Settings* option, *Cal* tab and *Crystal Calibration* field. The entry is in parts per million (ppm). A positive value is entered if the oscillator frequency is lower than it should be. In terms of a spectrum or waterfall frequency display, if the displayed frequency is lower than it should be, the ppm entry would be positive. Calibration is made using a low resolution bandwidth (RBW) and with FFT averaging to smooth the display.

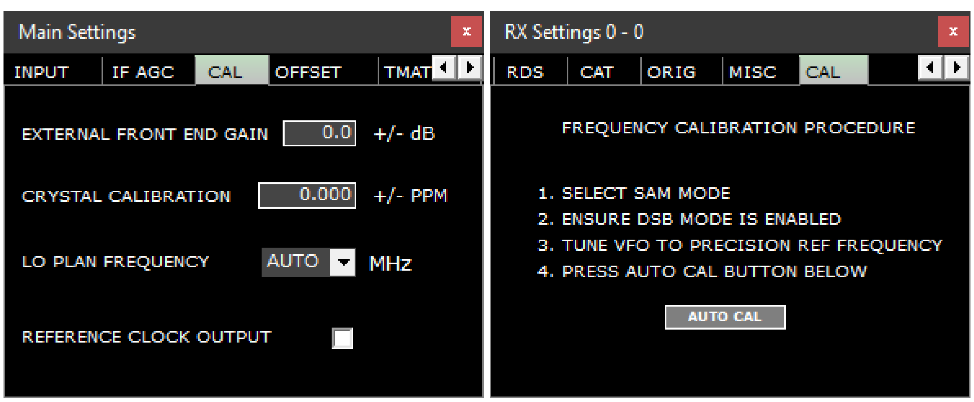

Figure 9 ~ Manual (left) and semi-automatic (right) frequency calibration windows in SDRuno. The manual method requires a specific error correction value while the automatic method requires an input signal with a precise frequency.

The automated method is accessed in the *Receiver (RX) Control* panel, *Settings* option, *Cal* tab and is self-explanatory. This calibration method requires an external precision frequency source connected to the receiver's antenna input port. The source could an antenna receiving a good signal from a time-frequency station (for example, WWV or WWVH) or an RF signal generator locked to a precision frequency source. After the automated calibration is used, the resulting correction in ppm can be viewed in the window for the manual method described in the previous paragraph. Once calibration is performed, SDRuno associates the correction with the receiver serial number and saves the offset on the PC used for calibration. Thus, the receiver frequency must be recalibrated if it is moved to another PC.

I noted that the RSPduo displays a strong spectral component (figure 10) at 24 MHz when it is operated both with and without the Mini-GPS Reference Clock. Oscillator harmonics to at least 120 MHz as well as subharmonics at 6 and 12 MHz also are present. All SDRPlay receivers use the same oscillator frequency and may or may not show these same characteristics, but I tested only the RSPduo.

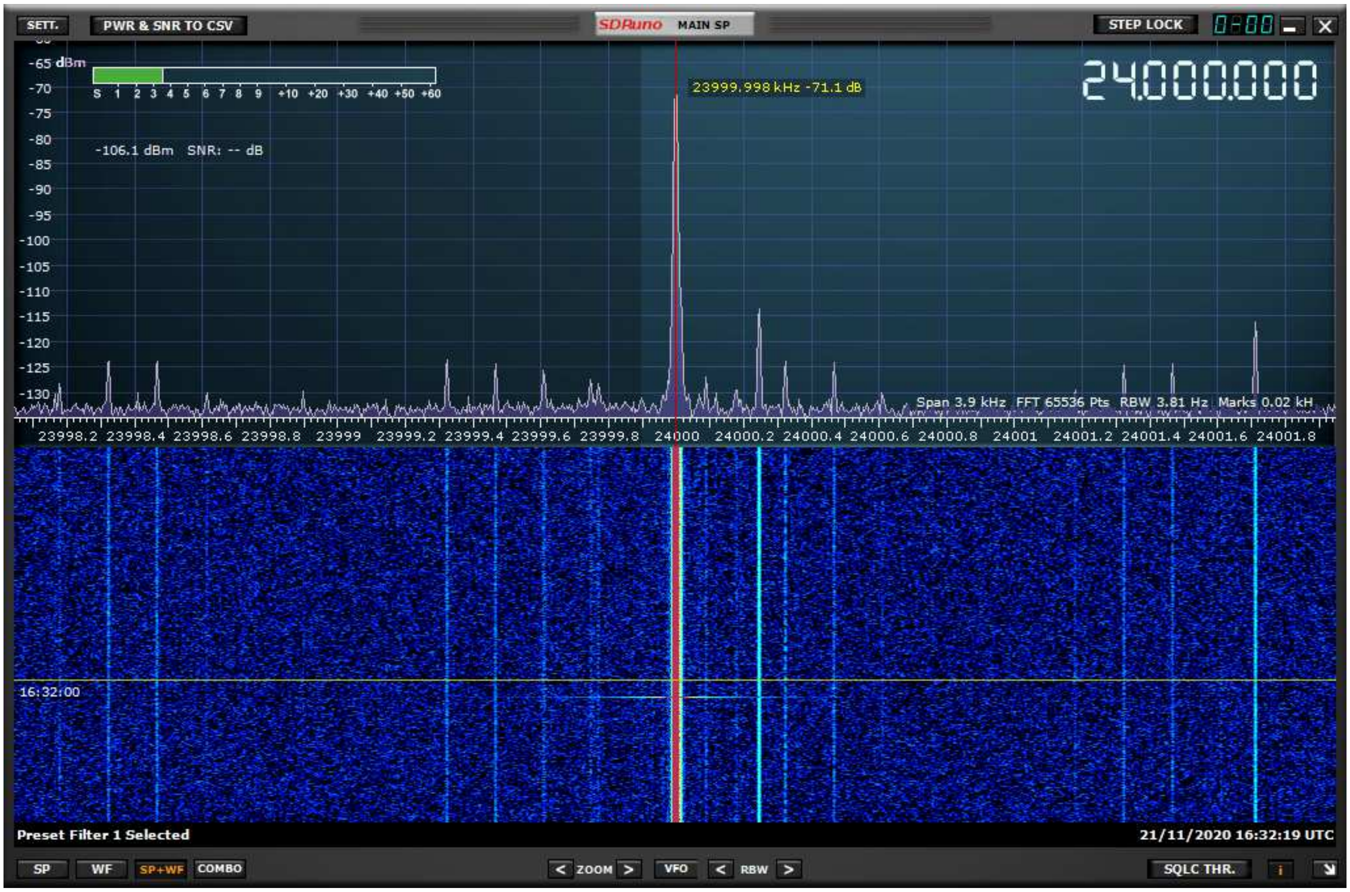

Figure 10 ~ SDRuno screenshot showing the strong 24 MHz oscillator spectral component in the SDRduo receiver; the cursor has been placed at its peak (in the upper-center of the plot) and indicates –71,1 dBm. Other spurs also are visible within the 3.9 kHz displayed span but they are relatively weak and their origin is unknown (the receiver was connected to a wideband HF antenna at the time).

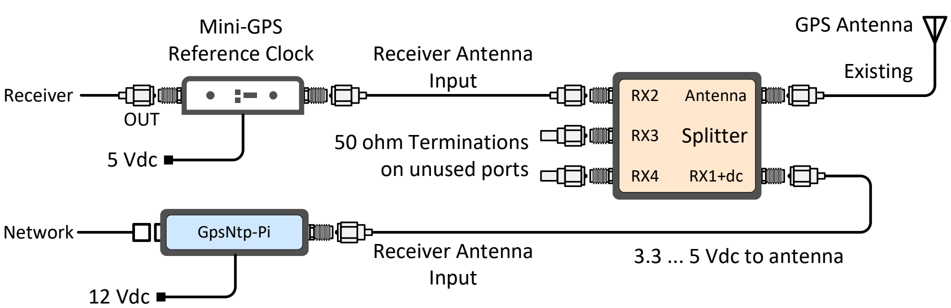

Figure 11 ~ Connection of the 4-port GNSS receiver antenna splitter to a single antenna and two receivers. The amplifiers in the splitter and antenna are powered by the bias-tee in the lower receiver. Image © 2020 W. Reeve

An observatory may use the Mini-GPS Reference Clock to improve receiver frequency accuracy as well as a GNSS-based device to improve PC real-time clock accuracy. These devices are separate so the observatory ends up with two GNSS antennas. For example, I use the GpsNtp-Pi NTP time server {GpsNtp-Pi} in my observatories for accurate time-stamping and the Mini-GPS Reference Clock for the SDRPlay receivers. Each GpsNtp-Pi has its own antenna as does the Mini-GPS Reference Clock. To reduce the number of cables and antennas, I installed a 4-port splitter to operate the devices from one antenna (figure 11). This particular splitter (figure 12) is designed and sold by {SV1AFN}. Note that an ordinary passive RF splitter cannot be used because of the antenna powering requirements. There appears to be no operational difference if the unused splitter ports are not terminated as they must be with passive splitter, but it is good practice to always terminate unused RF ports anyway.

Figure 12 ~ SV1AFN GNSS 4-port antenna splitter. One receiver port is used to supply dc power to the antenna port (right). The other three ports (left) provide a passive load to the receiver antenna inputs to prevent an "antenna fail" alarm condition. Dimensions are 1.9 L x 1.7 W x 0.7 in H (49 x 44 x 18 mm). Images © 2020 W. Reeve

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5. Setup Procedures

The following procedures ensure that the SDRPlay receiver works without locking up. The first set of procedures is for setting up the mini-GPS Reference Clock, the second set is for using the reference clock with the SDRPlay receivers, and the third set is for shutting down the receiver and its software in an orderly manner.

Setup the mini-GPS Reference Clock:

1) Connect the mini-GPS Reference Clock (Clock) to its antenna (the antenna should have a clear view of the sky. The antenna can be indoors near a window and does not necessarily have to be outdoors. Do not connect the mini-GPS Reference Clock to the receiver;
2) Connect the mini-GPS Reference Clock to a PC USB port and open its configuration tool:
   a. Check satellite Status – green bars, *GPS signal OK* and *PLL lock OK* (figure 13);
   b. Set the output frequency to *24 000 000* Hz (without spaces) and click *Set Frequency*;
   c. Click *Advanced* and the right window frame will open;
   d. Set the *Output Drive Strength* to 8 or 16 mA and be sure the *Enable* output box is checked. The setting should take effect immediately;
   e. Note that Position and Time are shown at the bottom of the right frame, which indicates a satellite fix;
   f. Click *Advanced* again to close the right frame;
   g. Close the configuration tool.
3) The mini-GPS Reference Clock settings are non-volatile, so it may be left connected to the PC USB port or reconnected to a dedicated 5 Vdc power source.

Install and use the SDRPlay receiver with the mini-GPS Reference Clock:

1) Be sure the receiver is disconnected from the PC USB port;
2) Connect the preconfigured mini-GPS Reference Clock output to the RSPxx Reference Input
   a. If RSP2 or RSP2Pro, connect the mini-GPS Reference Clock through an Isolator/load interface
   b. If RSPduo or RSPdx, connect directly, no interface is needed;

3) Connect the RSPxx to the PC USB port and listen for enumeration or check Device Driver for the *SDRPlay (RSPPxx)* entry under the *Sound, video and game controllers* devices;
4) Open SDRuno and click *Play*. Set the receiver frequency, mode and other parameters as needed.

Shutdown the SDRPlay receiver and mini-GPS Reference Clock:

1) Click *Stop* in SDRuno;
2) Close SDRuno;
3) Unplug the RSPxx from the PC USB port;
4) Disconnect the mini-GPS Reference Clock from the RSPxx Reference Input port;
5) The RSPxx may now be used without the external frequency reference by reconnecting it to the PC USB port and opening SDRuno.

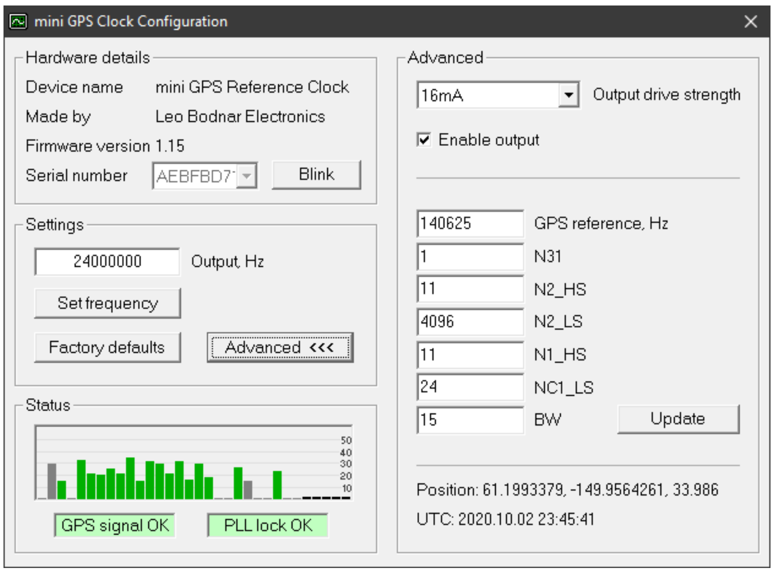

Figure 13 ~ Software configuration tool for the GPS Reference Clock. The basic window contains only the left frame. Note the satellite *Status* shown at the bottom of the left frame, which shows the relative received signal levels. Also indicated there are red or green labels that indicate the satellite signal availability for timing purposes and the status of the phased-locked loop. The latter indicates OK (as shown here) when the output is locked to either the satellites or the disciplined internal oscillator. Clicking *Advanced <<<* opens the right frame for setting and enabling the output level. The *Update* button in the right frame is used only to change the fields associated with the internal synthesizer (these are beyond the scope of this article).

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6. References and Weblinks

{GpsNtp-Pi} Reeve, W., GPS Network Time Server on Raspberry Pi: GpsNtp-Pi, 2015, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_GpsNtp-Pi.pdf

[ITU] ITU-R 22.HDB (2013), Handbook on Radio Astronomy, International Telecommunication Union, Radiocommunication Bureau, available at: https://www.itu.int/pub/R-HDB-22-2013

{mini-GPS} http://www.leobodnar.com/shop/index.php?main_page=product_info&products_id=301

{SDR-Kits} https://www.sdr-kits.net/GPS-Disciplined-Reference-Oscillator-for-DG8SAQ-VNWA

{SV1AFN) https://www.sv1afn.com/en/gnss-gps/-7.html

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