Evaluation of the Accuracy of the Power Display in SDRUno and the RSP1-A

RS Flagg, July 26, 2021

Introduction

The JOVE project is currently analyzing an SDRPlay RSP1-A that may be able to provide calibrated amplitude data to SkyPipe without the use of an external calibrated noise source. The RSP1-A, when used with SDRUno software, generates a digital readout of antenna input signal strength expressed in dBm (decibels below one milliwatt). This number can be read from the SDRUno display and is also available via an undocumented plug-in that can pass the number to SkyPipe (after conversion to antenna temperature).

Purpose

The purpose of this experiment is to provide a range of known signal strengths at the RSP1-A antenna input and determine how accurately the SDRUnp dBm display tracks the input signal amplitudes. No attempt is made to evaluate the utility of the SDRUno plug-in and SkyPipe display. The SDRUno antenna input power level will simply be read visually from the display and compared with the known input signal amplitude provided by a calibrated noise source and a step attenuator.

Procedure

The noise source (an HP461) has been calibrated using the Typinski laboratory grade standard 5722 noise source and has a temperature of 73MK. To develop a range of temperatures lower than the HP461 output the noise source signal will be passed thru a KAY 432D toggle switch attenuator (SN A11423). Attenuation (and hence temperature) can be varied in 1 dB steps. (3 dB steps are used in this experiment)

To compare the temperature of the attenuated noise source with the dBM reading in SDRUno we must first convert the noise temperature to dBm. The relationship between temperature and power is given by **P=kTB**, where (P) is power in watts, (k) is Boltzmann's constant (1.38E-23 J/K), (T) is temperature in Kelvins and (B) is bandwidth in Hz.

To determine P we must set a value for B, the receiver bandwidth. In SDRUno with the demodulation mode set to AM the available bandwidths are 6, 8, 11, and 20 kHz. I will use 8 kHz for this test.

The temperature in Kelvin at the attenuator output is calculated using:

T= ((Gen Temp in L)*10^(-atten/10)) +(290*(1-10^(-atten/10)))

Once power in watts has been obtained from P=kTB that value is multiplied by 1000 to get power in milliwatts. The number of dB above or below one milliwatt in dBm is simply:

dBm = 10*LOG(Pmw/1)

Noise Figure of RSP-1A

Like any amplifier, the RSP1-A generates internal noise which when referenced to the input of the device can be expressed as the device Noise Figure. The noise figure of the RSP1-A (per SDRPlay specifications) is 15 dB which can also be expressed as an equivalent temperature. In the case of the RSP1-A this temperature is 8880 Kelvin. This temperature must be added to the noise temperature delivered from the HP461 and the Kay attenuator.

Table 1 shows, as a function of attenuation in dB, the temperature at the input to the RSP1-A expressed in Kelvin and also the input power level in dBm given a bandwidth of 8 kHz. Larger negative dBm numbers represent weaker signal levels. The equivalent noise temperature of the 1A has been included.

Atten dB	Temp Kelvin	Temp +NF Kelvin	dBm
0	7.30E+07	7.30E+07	-80.94
3	3.66E+07	3.66E+07	-83.94
6	1.83E+07	1.83E+07	-86.93
9	9.19E+06	9.20E+06	-89.93
12	4.61E+06	4.62E+06	-92.93
15	2.31E+06	2.32E+06	-95.92
18	1.16E+06	1.17E+06	-98.90
21	5.80E+05	5.89E+05	-101.87
24	2.91E+05	3.00E+05	-104.80
27	1.46E+05	1.55E+05	-107.67
30	7.33E+04	8.22E+04	-110.42
33	3.69E+04	4.58E+04	-112.97
36	1.86E+04	2.75E+04	-115.18
39	9.48E+03	1.84E+04	-116.93
42	4.90E+03	1.38E+04	-118.18
45	2.60E+03	1.15E+04	-118.97
48	1.45E+03	1.03E+04	-119.43
51	8.70E+02	9.75E+03	-119.68

Table 1

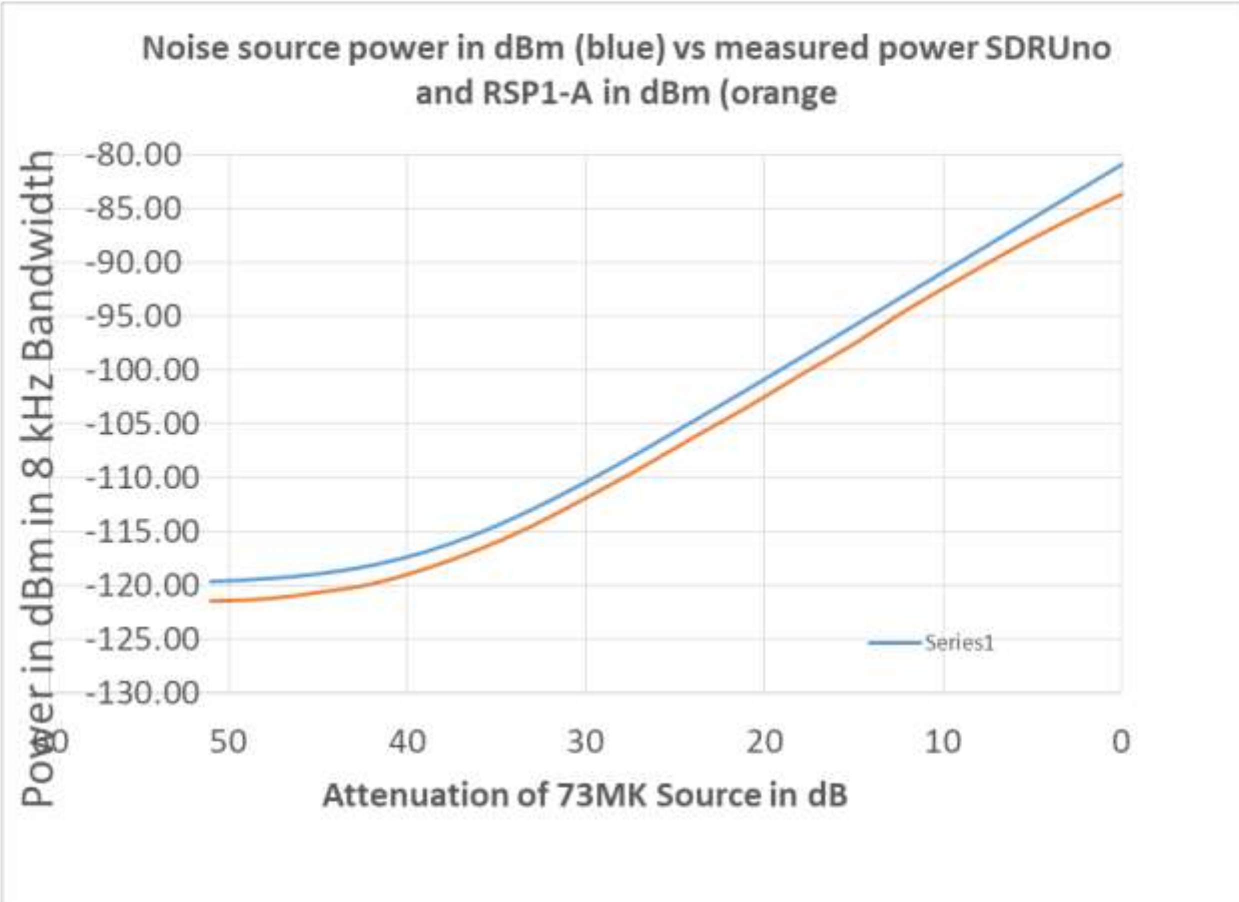

Figure 1 The input power to the RSP1-A in dBm is shown by the blue line. The input power level reported by SDRUno is shown by the orange line.

In Figure 1 above we see that SDRUno reports power levels somewhat lower than the actual input power. The error (gap between blue and orange) gradually increases as the input power increases (above about -90 dBm).

For reference, the galactic background signal presented to the 1A from a JOVE antenna and a coax cable with 3 dB of loss (and no multicoupler) is about 25kK, which is equivalent to -115.6 dBm.

It's difficult from this plot to determine how much of an error exists in the SDRUno power reading – the error appears to be relatively constant from -115 dBm to about -90 dBm. The dynamic range from -115 to -90 dBm is of course 25 dB – way more than required for Jupiter and on the order of what is needed for most strong solar bursts.

The plot in Figure 2 shows the error in more detail, giving us a better idea of what the useable dynamic range actually is.

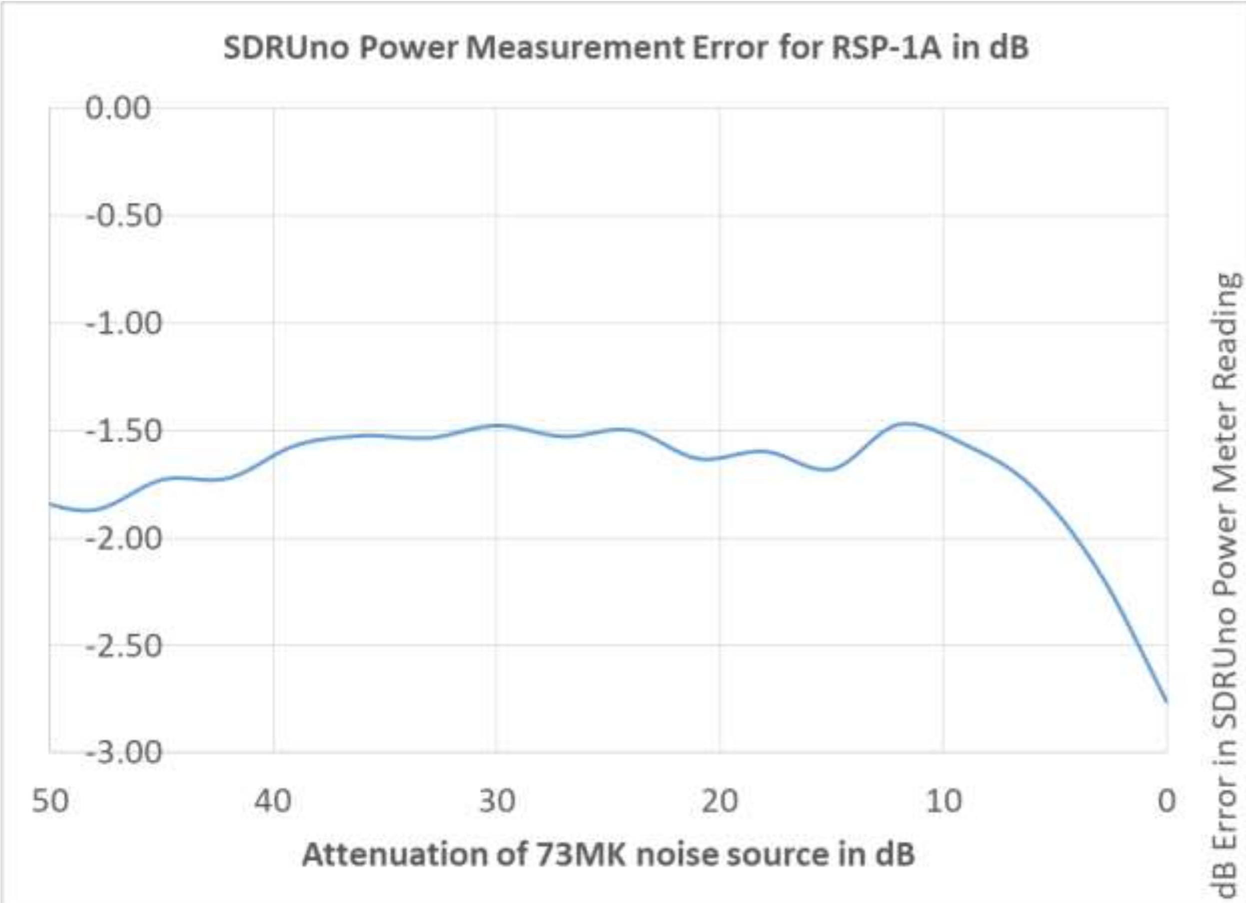

Figure 2 The vertical scale is measurement error in dB and the horizontal axis should be in 5 dB increments (Microsoft Excel refuses to do what I ask it to do).

Despite the axis labeling problems we can see that the error curve is close to -1.5 dB over at least a 30 dB range. For signals stronger than -115 dBm the error is less than -1.5 dB up to about 10 dB (7 MK). A dynamic range of 25 dB is more than adequate for Jupiter but a little shy for the strongest solar bursts..

Why the Error

The small error below -115 dBm is not of any real benefit in increasing the useful dynamic range to JOVE as long as our antenna is delivering approximately -115 dBm from the galactic background. An RSP1A connected to a TFD will benefit as the galactic background temperature will be lower due to the antenna inefficiency.

The digital bandpass filter (determining the 8 kHz bandwidth) is close to rectangular in shape according to SDRPlay tech support. The shape of the curve used to arrive at the relationship between the ADC output and the actual power at the input to the 1A is the average of the response of several units and so may be off slightly for any given unit.

SDRUno settings

SDRUno has controls for many parameters such as frequency, mode, bandwidth, gain, automatic gain control (AGC), volume, and an amplitude limiter. AGC can be turned on and off and gain adjusted manually.

Intermediate frequency, IF AGC characteristics are found under the main settings menu.   If the IF AGC box is checked then the AGC is ON.

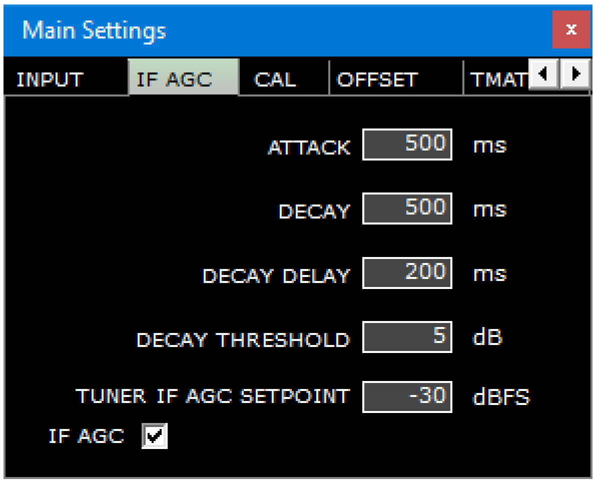

Figure 3 AGC ON

If unchecked then a manual gain slider may be used to adjust the gain

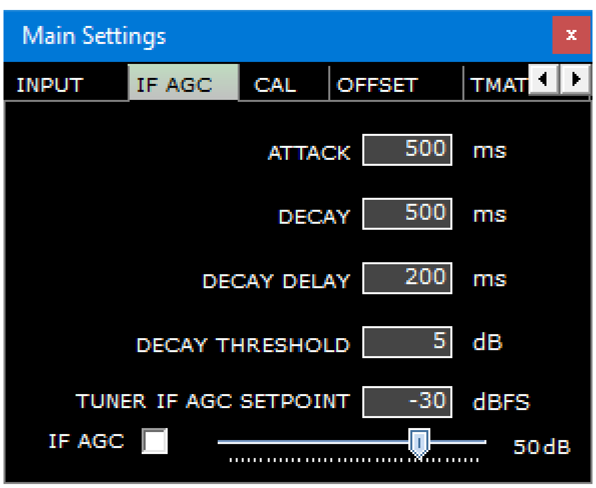

Figure 4 AGC OFF – manual gain

The Main Window (below) displays total gain (upper right below IFBW)

Figure 5

The RX control panel contains the volume, squelch, frequency, mode, bandwidth and AGC on/off and time constant controls. Just to the upper right of the frequency readout is the input power reading in dBm.

Figure 6

The RX settings panel allows the audio limiters to be turned on and off.

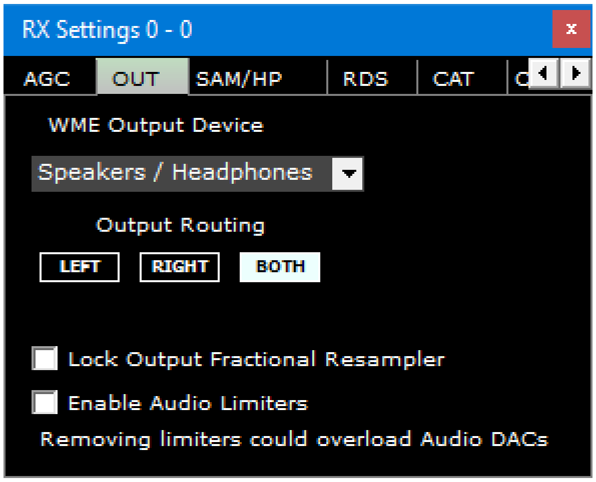

Figure 7

One might assume that the power reading in dBm would be independent of various parameter settings such as gain and AGC. They of course should depend on the input temperature and the IF bandwidth. We should probably confirm this assumption with SDRPlay.

I ran thru multiple gain settings with the AGC (main panel) off and found that with the maximum gain setting of the slider I got the same results as with the IF AGC on. The low signal reading got worse as I dropped the slider to low settings (like 24 dB gain).

Parameter	Panel	On/Off	Other
OS			Win 10
SDRUno ver #			1.40.2
RSP1A Serial #			1803020194
IF AGC	Main	ON	
Frequency	RX Control		20.1
Mode	RX Control		AM
Bandwidth	RX Control		8 kHz
Audio Limiter	RX Settings	OFF	
AGC	RX Control	OFF	

Table 2 Measurement settings

One thing should be obvious from this report – the control panels of SDRUno are complex.

Any testing must denote the state of the many control parameters.

Conclusion

The power reading in SDRUno includes the power due to the SDR noise figure temperature. Our measurement of a 1.5 dB error over a wide dynamic range seems consistent with the methodology used by SDRPlay to generate their power reading. The rather arbitrary JOVE hope for the antenna temperature measurement accuracy has been stated as +/- 1 dB. Without a larger statistical sample it is hard to say how close to that desired accuracy we will come with any given unit. It should be noted that we have probably been iiving with errors of this magnitude with our calibration method using the RF2080 and the JOVE receiver.

In terms of complexity there is a large advantage in using the SDRUno signal strength data (converted to antenna temperature) without the need for an external hardware calibrator.

If JOVE were to sell RSP1A units it would be possible to run a calibration curve and determine the bias in power readings for each individual unit. This bias correction number could be plugged into the software which converted the SDRUno power reading to antenna temperature resulting in a very accurate measure of antenna temperature without the need for an external hardware calibrator.