Callisto Gain Settings

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Introduction

The gain of the Callisto solar radio spectrometer is determined by the [agclevel] parameter in the configuration file (callisto.cfg). The parameter specifies the PWM (Pulse Width Modulation) setting used by the processor to control the RF tuner gain. if the setting is too high, front-end overload and distortion may occur; if too low, the receiver sensitivity may suffer. The relationship between the PWM setting and the receiver gain is the subject of this article.

The optimum setting usually is determined experimentally based on the gain of the user's system including the antenna, low noise preamplifier (if any), and coaxial cables. Many installations use an up-converter to enable observations at frequencies below 45 MHz, which is the lower frequency limit of the tuner in the Callisto instrument (the native tuning range is 45 to 870 MHz). The up-converter may have gain or loss, depending on its design, and this also must be taken into account in the Callisto PWM setting.

Gain control circuit

The Callisto processor outputs the PWM signal to a lowpass filter, which produces a dc voltage that is the average of the PWM waveform (figure 1). The voltage is applied to the RF and IF gain control pins of the RF tuner through a resistive voltage divider (figure 2). The [agclevel] parameter can be set anywhere in the range 0 to 250 and the resulting filter output voltage can vary from approximately 1.2 to 2.5 Vdc (figure 3). The actual voltage at the output of the lowpass filter can be read back through a serial terminal Command Line Interface for troubleshooting purposes or through the NF.exe software tool used during manufacture test of the instruments.

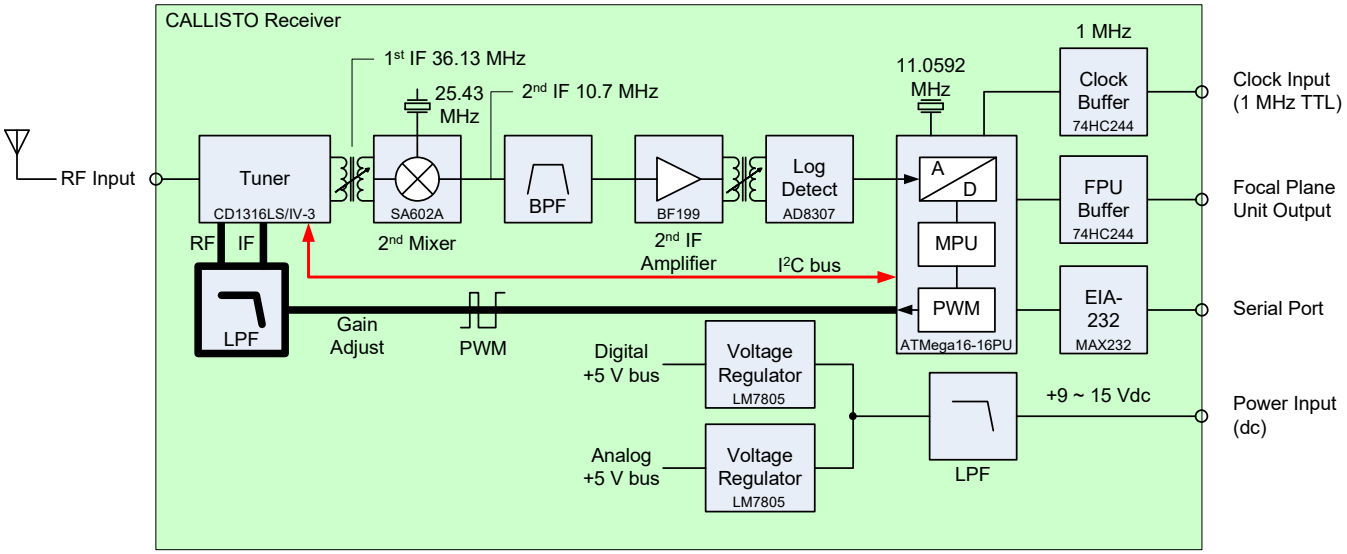

Figure 1 ~ Callisto block diagram. The gain control circuit is shown by heavy black lines from the ATMega processor to the tuner through the lowpass filter. Both RF and IF gains are proportionately controlled. Because of the tuner design, the IF gain voltage is set to 36% of the RF gain voltage through a resistive voltage divider.

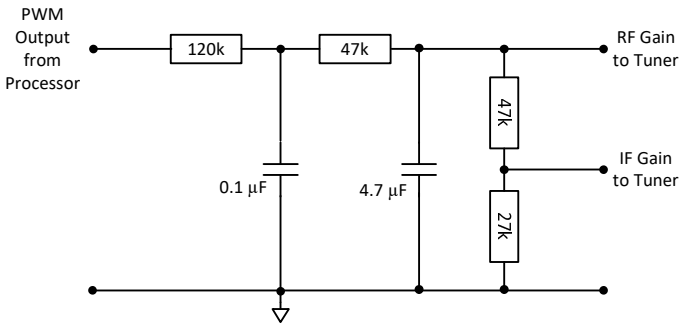

Figure 2 ~ Gain control circuit showing the PWM lowpass RC filter and voltage divider for the RF and IF gain inputs to the RF tuner.

The voltage measured at the instrument's log detector output is plotted as a function of RF input signal level for PWM settings of 50 through 250 (figure 3). The Callisto linear dynamic range varies with the PWM setting. For example, with PWM = 250, the output is linear from about –80 to –110 dBm and with PWM = 50 is linear from about –55 to –100 dBm. An equivalent plot is provided showing the output after the log detector output voltage has been converted by the analog-digital converter (ADC) in the processor (figure 4). The log detector output in mV is converted into digits according to: Digits = (mV/2500) x 256. The original measured data is provided at the end of this document.

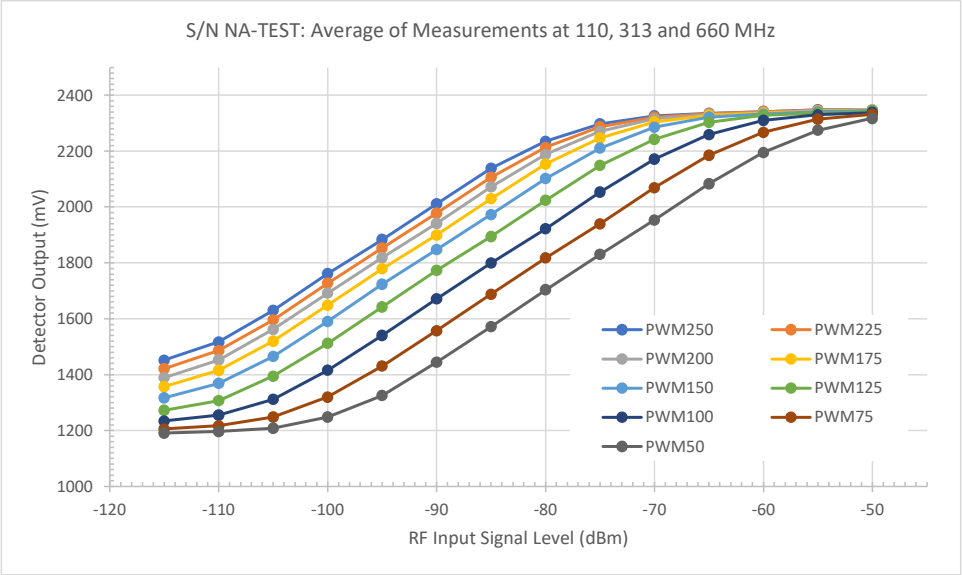

Figure 3 ~ Log detector output as a function of the RF input signal level for PWM settings from 50 to 250. The plotted values are the average of measurements in the middle of each RF tuner band as follows:
45 – 175 MHz: 110 MHz Ctr
175 – 450 MHz: 313 MHz Ctr
450 – 870 MHz: 660 MHz Ctr

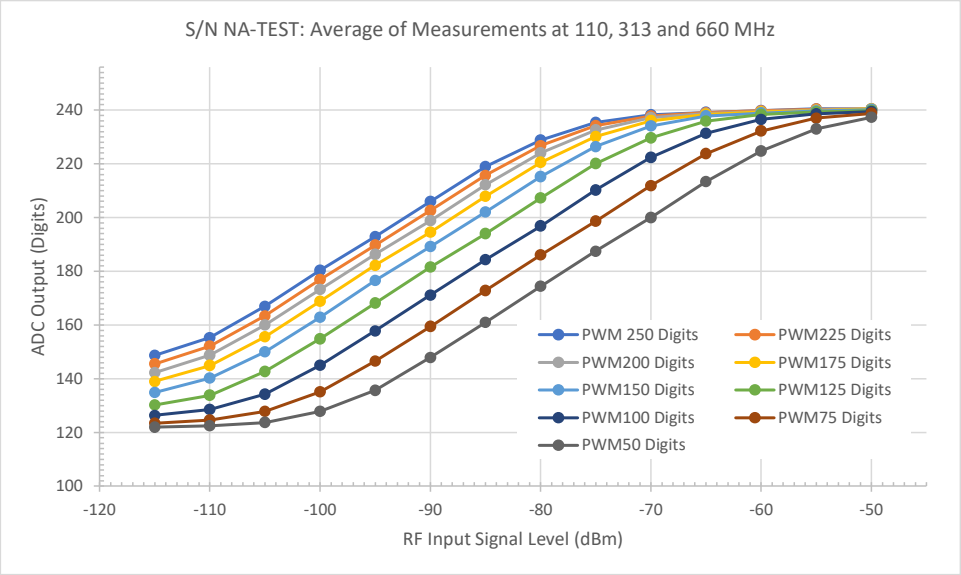

Figure 4 ~ ADC output digits as a function of the RF input signal level for PWM settings from 50 to 250. The plotted values are the average of measurements in the middle of each RF tuner band as follows:
45 – 175 MHz: 110 MHz Ctr
175 – 450 MHz: 313 MHz Ctr
450 – 870 MHz: 660 MHz Ctr

These plots help determine how much change to the PWM setting is necessary to provide more or less gain. Generally, it is desirable to set the gain such that the average, or background, level measured by the instrument is approximately 1/2 of the ADC full scale; that is, (2500 mV/2 =) 1250 mV or 128 digits

For an input power of –90 dBm (a level where all PWM settings produce a linear response curve), the output change is:
(2011 mV – 1671 mV) / (PWM250 – PWM100) = 2.27 mV/PWM = 0.23 digits/PWM

However, gain is not a linear function of the PWM setting over the full PWM range. A better PWM range is, say, PWM100 to PWM150, in which case the output change is:
(1848 mV – 1671 mW) / (PWM150 – PWM100) = 3.54 mV/PWM = 0.36 Digits/PWM

The change in the PWM setting is:
(Desired background digits – Existing background digits)/(0.36 Digits/PWM)

Example: Say the observed background level is 100 digits instead of the desired 128 digits. In this case, the PWM should be increased by about:
(128 Digits – 100 Digits) / (0.36 Digits/PWM) = 76 PWM.

For this example, the PWM would be increased from its present setting by 76. Say the present PWM setting is 105, then the setting would be increased from PWM105 to PWM181.

The reverse is also true. For example, if the present background level is 150 digits, then to have a desired level of 128 digits:
(128 Digits – 150 Digits)/(0.36 Digits/PWM = –61 PWM.

For this example, if the present setting is PWM180, the new setting would be PWM180 – 61 = PWM119.

Comments

- The above are approximations based on the measurements of one instrument. Slightly different results may be expected with different instruments. Also, the background noise levels at e-CALLISTO stations vary over a wide range. Therefore, the calculations described here provide only a starting point for the PWM setting at any given station and instrument. Experimentation will be necessary to find the optimum setting.
- The Callisto noise figure varies with PWM setting and is lowest (best) when the PWM setting is highest (near PWM250). The noise figure of the RF tuner in the Callisto degrades with lower PWM settings. When the Callisto is operated at lower PWM settings, it often means there is a preamplifier between the antenna and instrument. The preamplifier should be placed as near to the antenna as possible and designed for low noise and high enough gain so that it controls the system noise figure.
- The PWM setting in the configuration file callisto.cfg usually can be changed on the fly. However, not every Windows operating system supports this, so it is suggested that the callisto.exe application be restarted after changing the PWM setting in the callisto.cfg file.

The above plots are based on the following table of the log detector Output Voltage vs RF input Power for different PWM settings. The table shows the average values for measurements in the middle of each RF tuner band.

NA-TEST : No Enclosure : Average of measurements at 110, 313 and 660 MHz

Input Pwr	**PWM 250**	**PWM225**	**PWM200**	**PWM175**	**PWM150**	**PWM125**	**PWM100**	**PWM75**	**PWM50**
(dBm)	(mV)	(mV)	(mV)	(mV)	(mV)	(mV)	(mV)	(mV)	(mV)
-50	2347	2347	2347	2348	2346	2342	2338	2332	2317
-55	2348	2347	2344	2342	2341	2337	2330	2314	2275
-60	2342	2341	2338	2337	2333	2328	2310	2268	2195
-65	2335	2334	2332	2329	2322	2303	2259	2185	2084
-70	2326	2322	2316	2305	2286	2243	2172	2069	1953
-75	2298	2287	2271	2247	2211	2149	2053	1940	1831
-80	2235	2214	2188	2154	2102	2024	1922	1818	1704
-85	2138	2106	2072	2030	1973	1894	1800	1688	1572
-90	2011	1978	1941	1900	1848	1773	1671	1557	1444
-95	1884	1853	1819	1779	1724	1642	1541	1431	1325
-100	1761	1728	1692	1648	1590	1512	1416	1320	1248
-105	1630	1596	1562	1520	1465	1394	1311	1248	1208
-110	1517	1486	1453	1415	1369	1307	1255	1217	1196
-115	1452	1421	1390	1357	1317	1272	1234	1206	1191