X-band Continuum Source Baselines
Project TBASERDN031029, October 29, 2003

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Introduction

This report describes baseline test observations taken on October 29, 2003. The purpose was to investigate the effects of changing the 3-level sampler clipping levels by ± 3 dB to see if the sampler circuitry is contributing any noise to the 800 MHz bandwidth spectrum as measured by the GBT spectrometer. The observational test procedure was to take on-off spectrum pairs of the continuum source NGC 7027, The weather during these tests began with a few scattered clouds and went to clear during the evening. An Aurora Borealis display could be seen on the northern horizon.

Setup

At the duration of these tests the receiver LO1 was set to 12 GHz, and the LO2 synthesizers driving all converter modules were set to 12300 MHz to tune the spectrometer center channel to 9000MHz. Converter modules CM12 and CM16 were not available so Bank D was fed by CM4 and CM8. The system connections on October 29 were:

LCP	ODM6	CM9	SF1	Bank A, J1, Sampler 1
	ODM6	CM10	SF2	Bank B, J3, Sampler 1
	ODM6	CM11	SF3	Bank C, J5, Sampler 1
	ODM1	CM4	SF4	Bank D, J7, Sampler 1
RCP	ODM8	CM13	SF5	Bank A, J2, Sampler 2
	ODM6	CM14	SF6	Bank B, J4, Sampler 2
	ODM6	CM15	SF7	Bank C, J6, Sampler 2
	ODM3	CM8	SF8	Bank D, J8, Sampler 2

Continuum Source Spectra

The radio source NGC 7027 was used to measure the spectral response of the GBT system to continuum input to the receiver. This source has a flux density at 9 GHz of about 6 Jy, which will produce an antenna temperature of a bit over 10 Kelvins or roughly 40 percent of the system temperature. Before the on-off spectra were taken the antenna pointing was trimmed by adding small offsets to the commanded position to maximize the response to the radio source as measured on one of the IF Rack total power meters. During the test period of several hours the radio source passed close to the zenith so its azimuth was changing rapidly. Part way through the run we discovered that the pointing error had changed significantly, and a new peak-up on the source was executed.

Figure 1 shows the Tsrc/Tsys spectra for NGC 7027 from the two bank A spectrometer channels with one connected to the LCP receiver channel and one to the RCP channel. Three spectra with different sampler level settings are shown for each channel. The red curves were taken with the samplers running at their normal quantization voltage values and the power at the inputs to the spectrometer set to the optimum levels of about -17 dBm. The green curves were measured with the sampler quantization voltages set 3 dB lower (0.7 times) their normal values. The input powers to the spectrometer were set to -20 dBm by increasing the attenuation in the converter modules. The blue curves were measured with the sampler quantization voltages set 3 dB higher (1.4 times) their normal values, and the input powers to the spectrometer set to -14 dBm. The higher sampler voltage settings appear to produce less variation in the spectra across the band, particularly below 250 MHz and above 650 MHz. This would be consistent with significant noise being contributed by the sampler circuitry, but this is not necessarily the only explanation.

Figure 2 shows the ratios of the Tsrc/Tsys spectra shown in Figure 1. The red curves are the ratios of spectra with normal sampler levels to spectra with 3 dB higher levels, and the green curves are ratios of spectra with 3 dB lower sampler levels to spectra with 3 dB higher levels. Almost all of the baseline structure appears to be worse with lower sampler levels.

For comparison, Figures 3 through 8 show the Tsrc/Tsys and ratio spectra for the other three spectrometer banks whose sampler levels and input power levels were unchanged throughout the measurements. At least some of the slope in the green ratio curves is due to the pointing error, which causes a greater gain loss at the high frequency end of the spectra. Some of the baseline variation features seen in the ratio spectra for banks B through D are common to all three banks for the same front-end receiver channel, which suggests that there were drifts in the passband of components ahead of the power splitter at the outputs of the optical receiver modules. Not all features in the spectral are common to all three banks, however. The time between the beginning of scan 4 to the end of scan 12 was about two hours.

800 MHz Spectra with 200 MHz Filters

To look for residual noise in the samplers and other components following the anti-aliasing filters we switched to the 200-MHz bandwidth filters while using the 800-MHz spectrometer bandwidth sampler and autocorrelation mode. The 200-MHz bandwidth filters have a passband range of 800-1000 MHz, which is one quarter of the 800-1600 MHz passband of the 800-MHz bandwidth filters. The stop-band attenuation of the 800-1000 MHz is better than 60 dB so the frequency range of 1000-1600 MHz (0-600 MHz at baseband) should show less than 0.0001% of the power level in the 800-1000 MHz (600-800 MHz at baseband) passband.

Figures 9 through 14 show the measured on-source and off-source spectra from spectrometer banks A, B, and D. The attenuators in the analog filter rack feeding bank C were incorrectly set. The levels to all samplers in banks A, B, and D were set close to their normal operating levels. This required about 6 dB less than normal attenuation in the converter modules to compensate for the smaller analog bandwidth in the 800-MHz spectrometer mode. The amplified spectra in the 0-600-MHz frequency range show up to 0.5% of the spectral power density measured in the 600-800 MHz range. The power measured in the stop band could be at least partially due to errors in the VanVleck quantization correction. The negative power values in a few of the spectra show that, indeed, there is some correction error. This type of extreme spectral shape does stress the VanVleck correction considerably harder than normal. However, it seems unlikely that all of the power seen in the stop-band can be attributed to a VanVleck correction error. This tentatively suggests that components following the anti-aliasing filers could be contributing up to 0.5% of the total system noise power under normal operating conditions. This is roughly consistent with the observed changes in spectrum shape with different sampler quantization voltages and different sampler input levels in Figures 1 through 8 and the measurements of October 10 and 23.

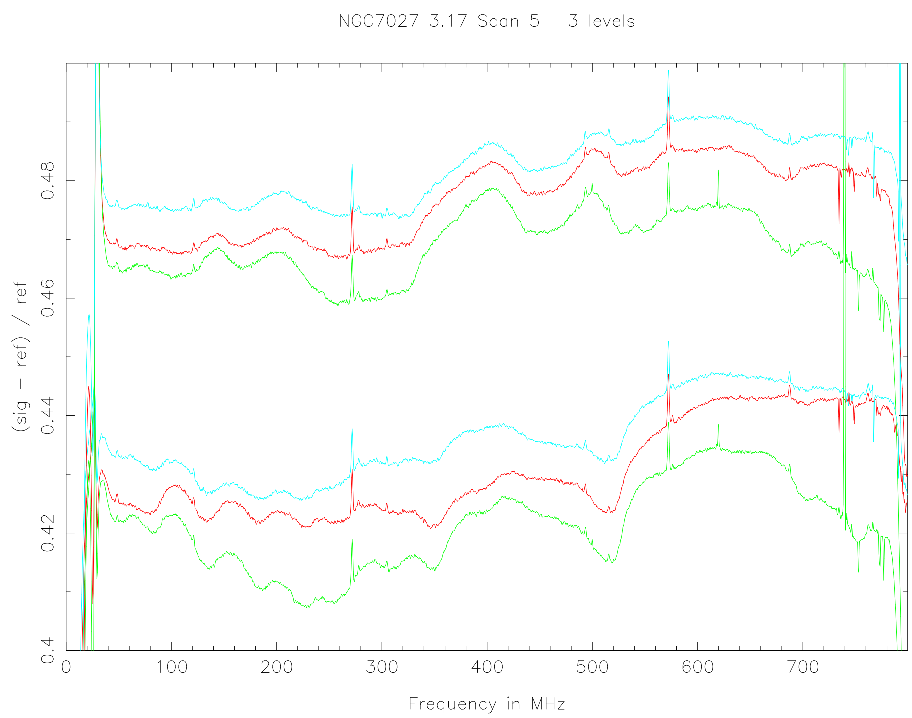

Figure 1: Scans 4-5, 7-8, 11-12: (on - off) / off, i.e. Tsrc/Tsys, spectra for the continuum source NGC 7027 using spectrometer bank A. The lower three traces are for the LCP receiver using samplers connected to spectrometer input J1, and the upper traces are for RCP connected to sampler input J2. The red traces are spectra with the sampler levels set to their normal levels. The green traces are with the sampler levels set 3 dB lower than normal (0.7 times their normal voltages). The blue traces are with the sampler levels set 3 dB higher than normal (1.4 times their normal voltages). The spectra are variously scaled by a few percent to present the curves for best comparison. In addition, the green curves are scaled up by about 12% to correct for gain loss due to a pointing error. The frequency scale of 0 to 800 MHz is for the sampler base band, which corresponds to 1600 to 800 MHz at the spectrometer inputs.

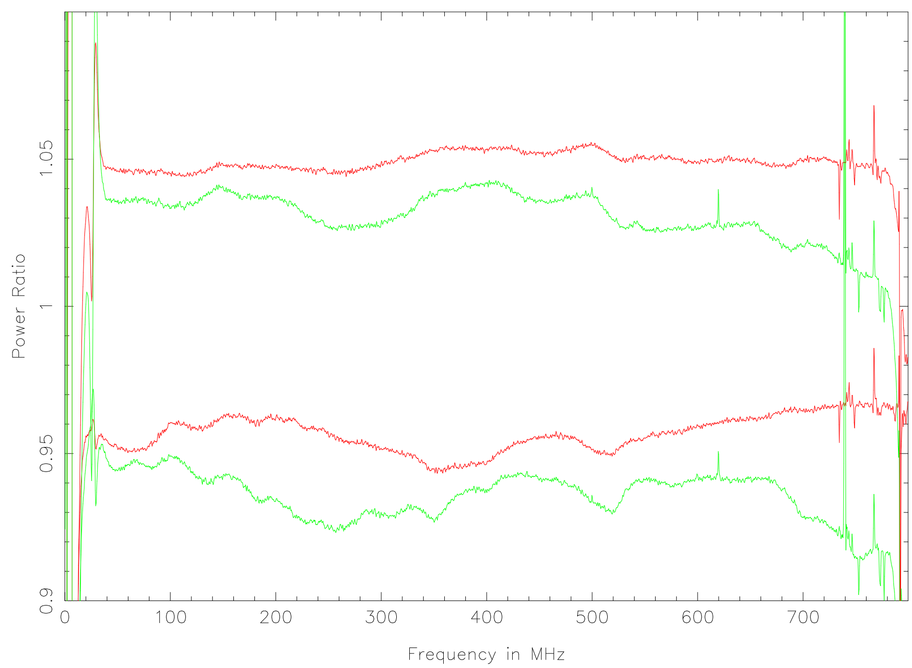

Figure 2: Scans 4-5, 7-8, 11-12: Ratios of (on - off) / off, i.e. Tsrc/Tsys, spectra for the continuum source NGC 7027 using different sampler quantization voltage levels. The lower two traces are for the LCP receiver using samplers connected to spectrometer input J1, and the upper traces are for RCP connected to sampler input J2. The red traces are ratios of spectra with normal sampler levels to spectra with 3 dB higher sampler levels. The green traces are ratios of spectra with 3 dB lower sampler levels to spectra with 3 dB higher sampler levels. The green curves are scaled up by about 12% to correct for gain loss due to a pointing error. The frequency scale of 0 to 800 MHz is for the sampler base band, which corresponds to 1600 to 800 MHz at the spectrometer inputs.

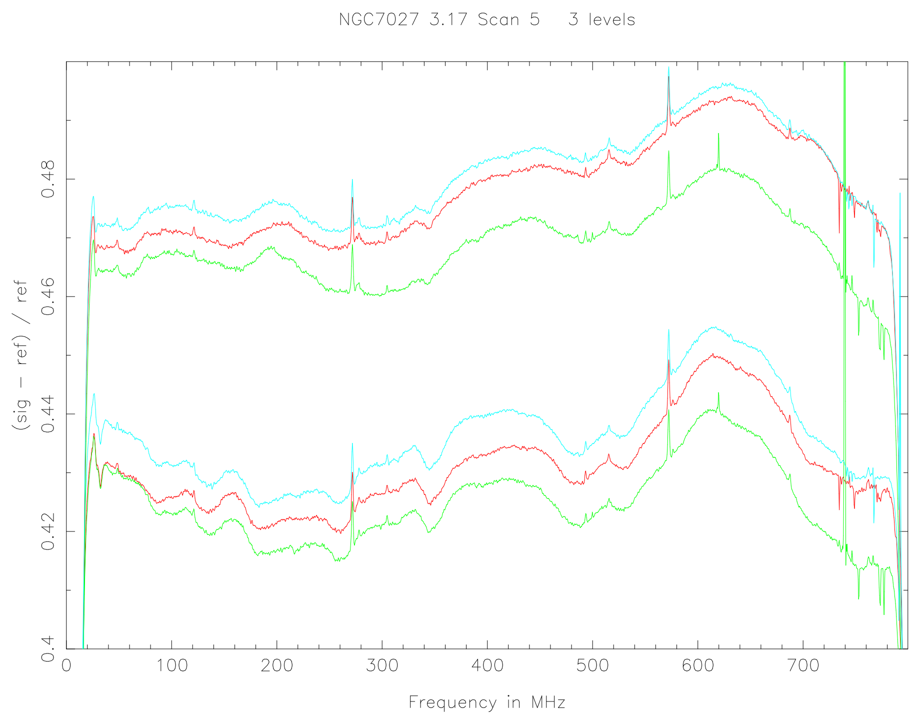

Figure 3: Scans 4-5, 7-8, 11-12: (on - off) / off, i.e. Tsrc/Tsys, spectra for the continuum source NGC 7027 using spectrometer bank B. The lower three traces are for the LCP receiver using samplers connected to spectrometer input J3, and the upper traces are for RCP connected to sampler input J4. The red traces are spectra from scan pair 4-5. The green traces are for scan pair 7-8. The blue traces are from scan pair 11-12. The spectra are variously scaled by a few percent to present the curves for best comparison. In addition, the green curves are scaled up by about 12% to correct for gain loss due to a pointing error. The frequency scale of 0 to 800 MHz is for the sampler base band, which corresponds to 1600 to 800 MHz at the spectrometer inputs.

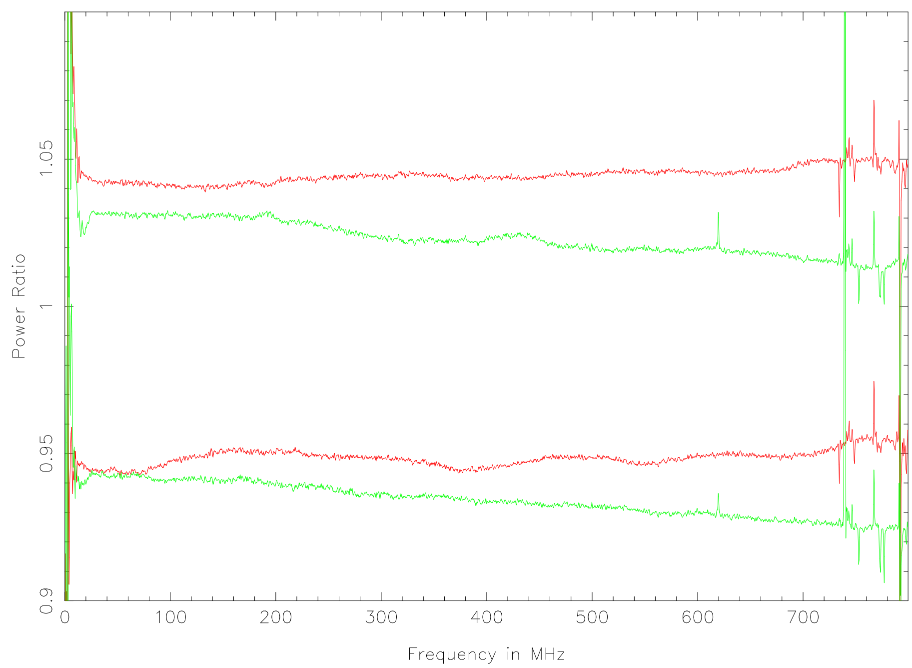

Figure 4: Scans 4-5, 7-8, 11-12: Ratios of (on - off) / off, i.e. Tsrc/Tsys, spectra for the continuum source NGC 7027 using spectrometer bank B. The lower two traces are for the LCP receiver using samplers connected to spectrometer input J3, and the upper traces are for RCP connected to sampler input J4. The red traces are ratios of scan 4-5 spectra to scan 11-12 spectra. The green traces are ratios of scan 7-8 spectra to scan 11-12 spectra. Sampler voltage levels and spectrometer input power levels were constant throughout the measurements. The green curves are scaled up by about 12% to correct for gain loss due to a pointing error. The frequency scale of 0 to 800 MHz is for the sampler base band, which corresponds to 1600 to 800 MHz at the spectrometer inputs.

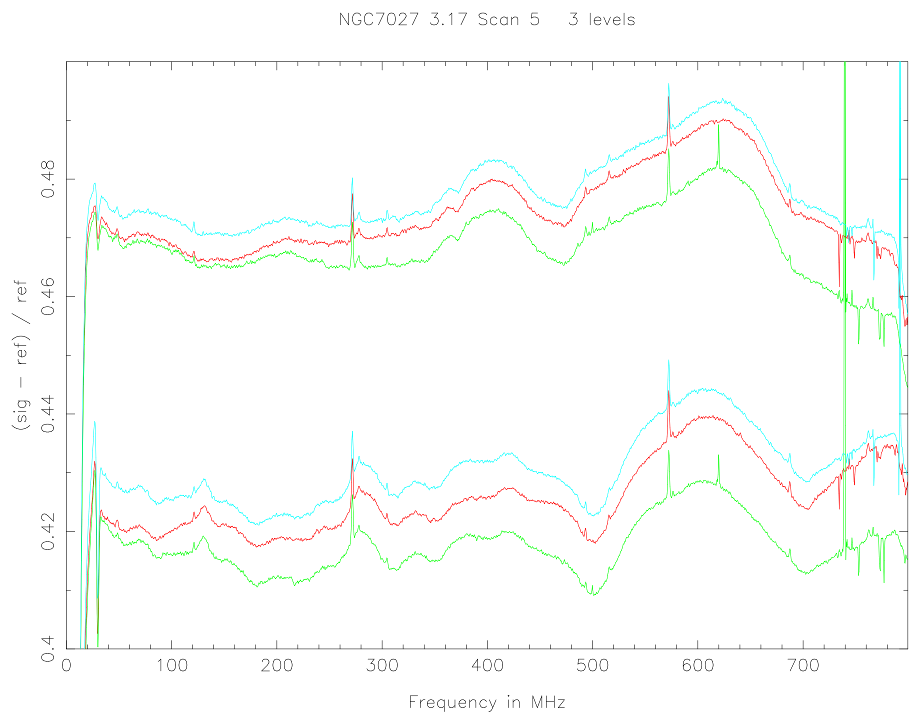

Figure 5: Scans 4-5, 7-8, 11-12: (on - off) / off, i.e. Tsrc/Tsys, spectra for the continuum source NGC 7027 using spectrometer bank C. The lower three traces are for the LCP receiver using samplers connected to spectrometer input J5, and the upper traces are for RCP connected to sampler input J6. The red traces are spectra from scan pair 4-5. The green traces are for scan pair 7-8. The blue traces are from scan pair 11-12. The spectra are variously scaled by a few percent to present the curves for best comparison. In addition, the green curves are scaled up by about 12% to correct for gain loss due to a pointing error. The frequency scale of 0 to 800 MHz is for the sampler base band, which corresponds to 1600 to 800 MHz at the spectrometer inputs.

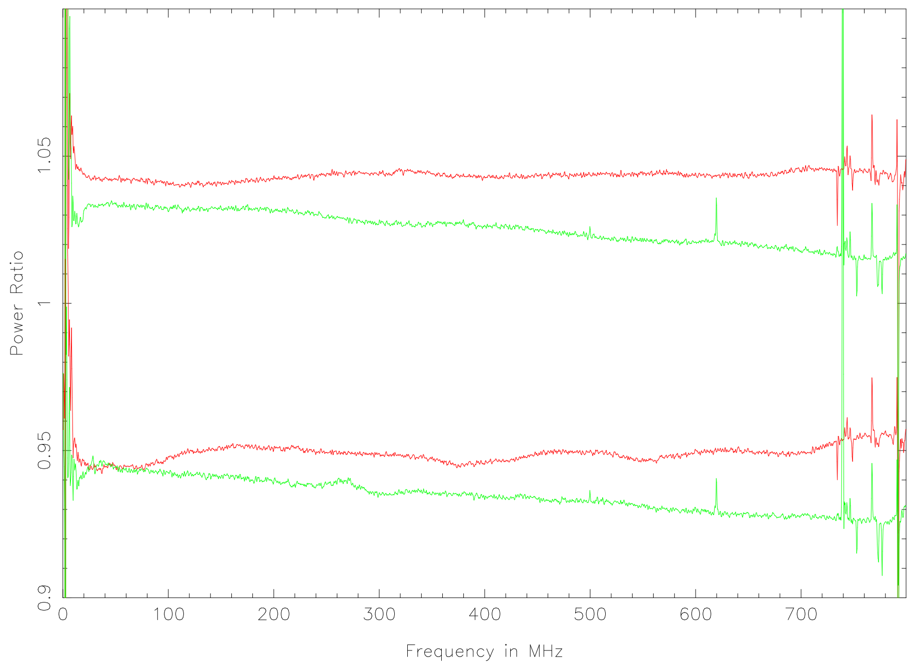

Figure 6: Scans 4-5, 7-8, 11-12: Ratios of (on - off) / off, i.e. Tsrc/Tsys, spectra for the continuum source NGC 7027 using spectrometer bank C. The lower two traces are for the LCP receiver using samplers connected to spectrometer input J5, and the upper traces are for RCP connected to sampler input J6. The red traces are ratios of scan 4-5 spectra to scan 11-12 spectra. The green traces are ratios of scan 7-8 spectra to scan 11-12 spectra. Sampler voltage levels and spectrometer input power levels were constant throughout the measurements. The green curves are scaled up by about 12% to correct for gain loss due to a pointing error. The frequency scale of 0 to 800 MHz is for the sampler base band, which corresponds to 1600 to 800 MHz at the spectrometer inputs.

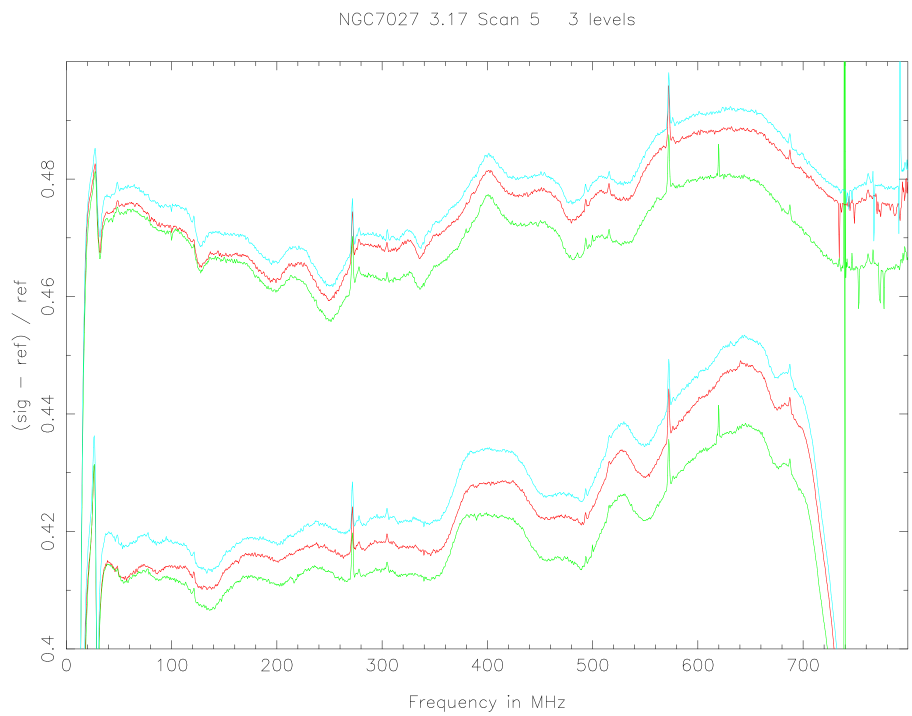

Figure 7: Scans 4-5, 7-8, 11-12: (on - off) / off, i.e. Tsrc/Tsys, spectra for the continuum source NGC 7027 using spectrometer bank D. The lower three traces are for the LCP receiver using samplers connected to spectrometer input J7, and the upper traces are for RCP connected to sampler input J8. The red traces are spectra from scan pair 4-5. The green traces are for scan pair 7-8. The blue traces are from scan pair 11-12. The spectra are variously scaled by a few percent to present the curves for best comparison. In addition, the green curves are scaled up by about 12% to correct for gain loss due to a pointing error. The frequency scale of 0 to 800 MHz is for the sampler base band, which corresponds to 1600 to 800 MHz at the spectrometer inputs.

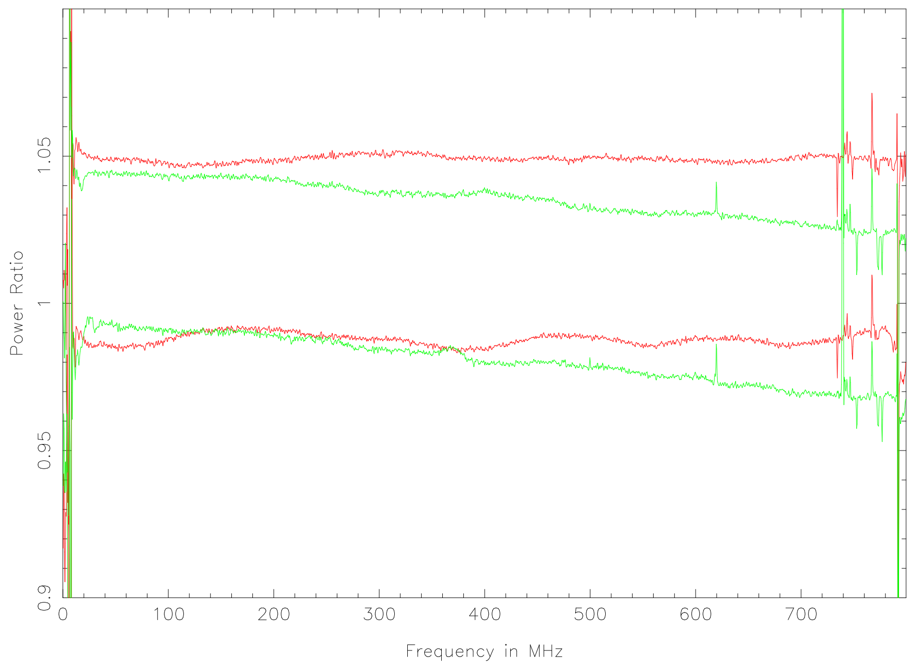

Figure 8: Scans 4-5, 7-8, 11-12: Ratios of (on - off) / off, i.e. Tsrc/Tsys, spectra for the continuum source NGC 7027 using spectrometer bank D. The lower two traces are for the LCP receiver using samplers connected to spectrometer input J7, and the upper traces are for RCP connected to sampler input J8. The red traces are ratios of scan 4-5 spectra to scan 11-12 spectra. The green traces are ratios of scan 7-8 spectra to scan 11-12 spectra. Sampler voltage levels and spectrometer input power levels were constant throughout the measurements. The green curves are scaled up by about 12% to correct for gain loss due to a pointing error. The frequency scale of 0 to 800 MHz is for the sampler base band, which corresponds to 1600 to 800 MHz at the spectrometer inputs.

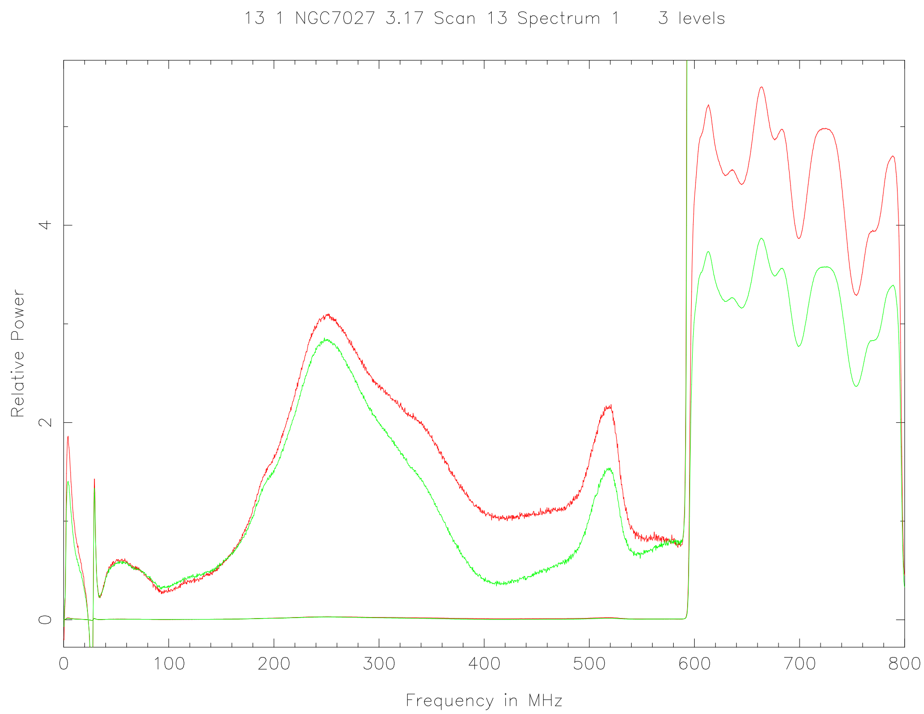

Figure 9: Scans 13-14: On and off total power spectra for the continuum source NGC 7027 using spectrometer bank A input J1 and a 200 MHz anti-alias filter in the analog filter module. The red trace is the on-source spectrum, and the green trace is off source. In the 0-600 MHz stop-band the spectra are replotted with 100 times the vertical scale.

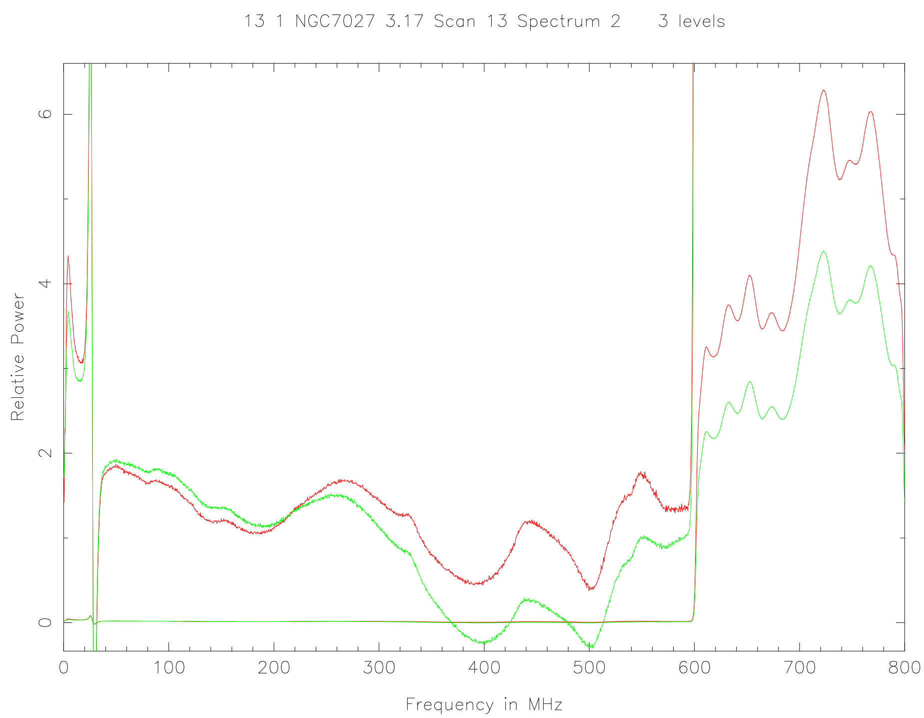

Figure 10: Scans 13-14: On and off total power spectra for the continuum source NGC 7027 using spectrometer bank A input J2 and a 200 MHz anti-alias filter in the analog filter module. The red trace is the on-source spectrum, and the green trace is off source. In the 0-600 MHz stop-band the spectra are replotted with 100 times the vertical scale.

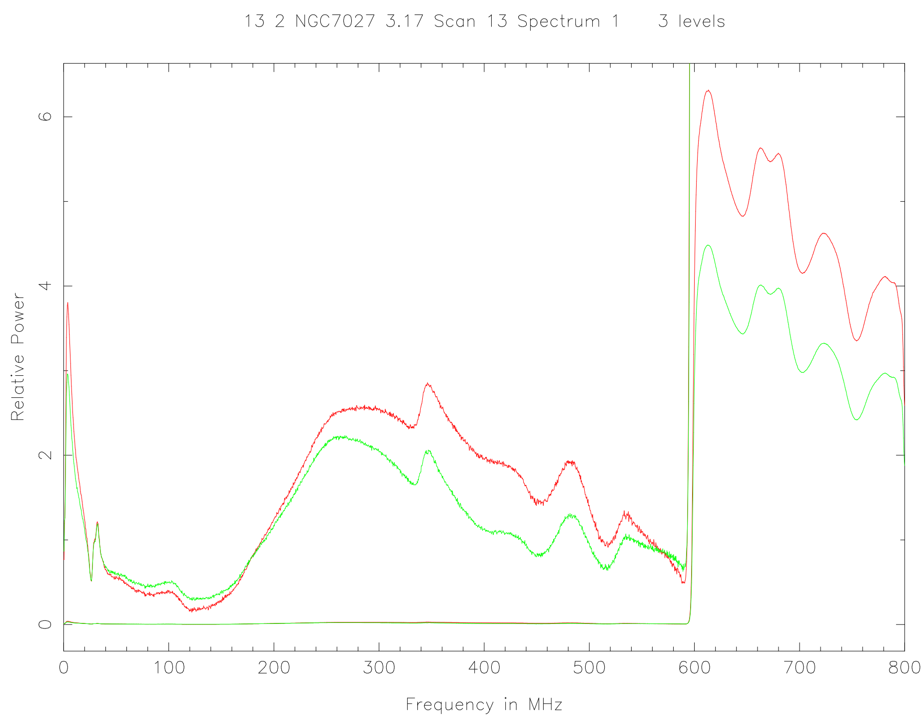

Figure 11: Scans 13-14: On and off total power spectra for the continuum source NGC 7027 using spectrometer bank B input J3 and a 200 MHz anti-alias filter in the analog filter module. The red trace is the on-source spectrum, and the green trace is off source. In the 0-600 MHz stop-band the spectra are replotted with 100 times the vertical scale.

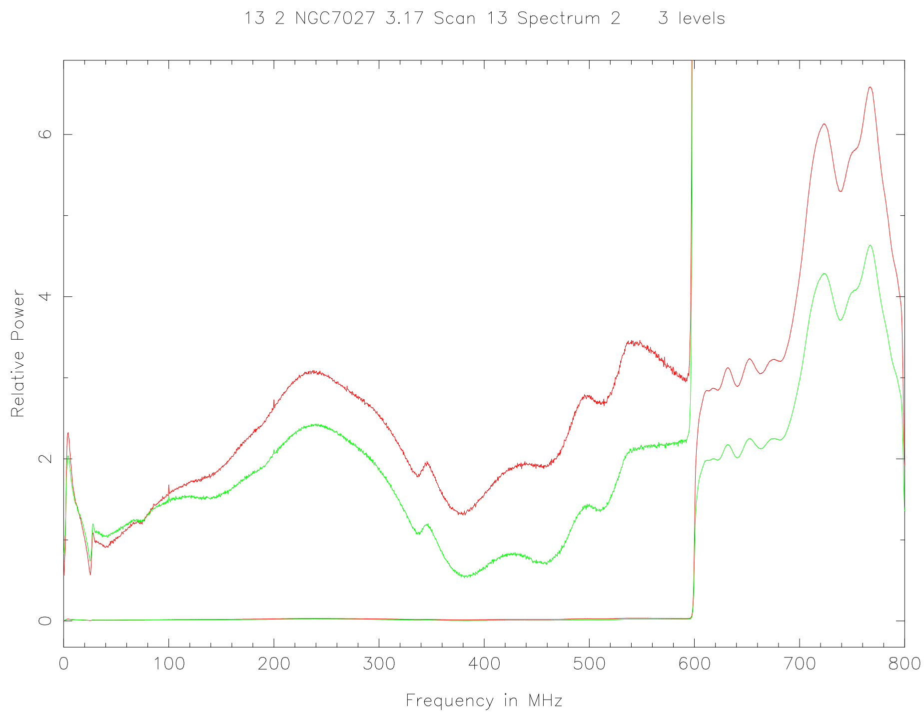

Figure 12: Scans 13-14: On and off total power spectra for the continuum source NGC 7027 using spectrometer bank B input J4 and a 200 MHz anti-alias filter in the analog filter module. The red trace is the on-source spectrum, and the green trace is off source. In the 0-600 MHz stop-band the spectra are replotted with 100 times the vertical scale.

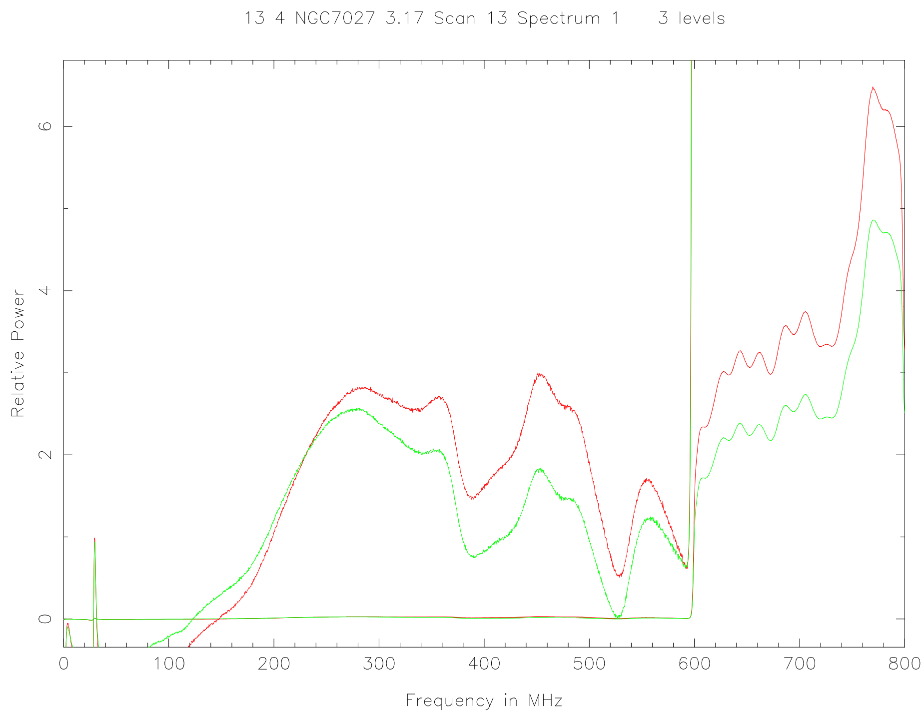

Figure 13: Scans 13-14: On and off total power spectra for the continuum source NGC 7027 using spectrometer bank D input J7 and a 200 MHz anti-alias filter in the analog filter module. The red trace is the on-source spectrum, and the green trace is off source. In the 0-600 MHz stop-band the spectra are replotted with 100 times the vertical scale.

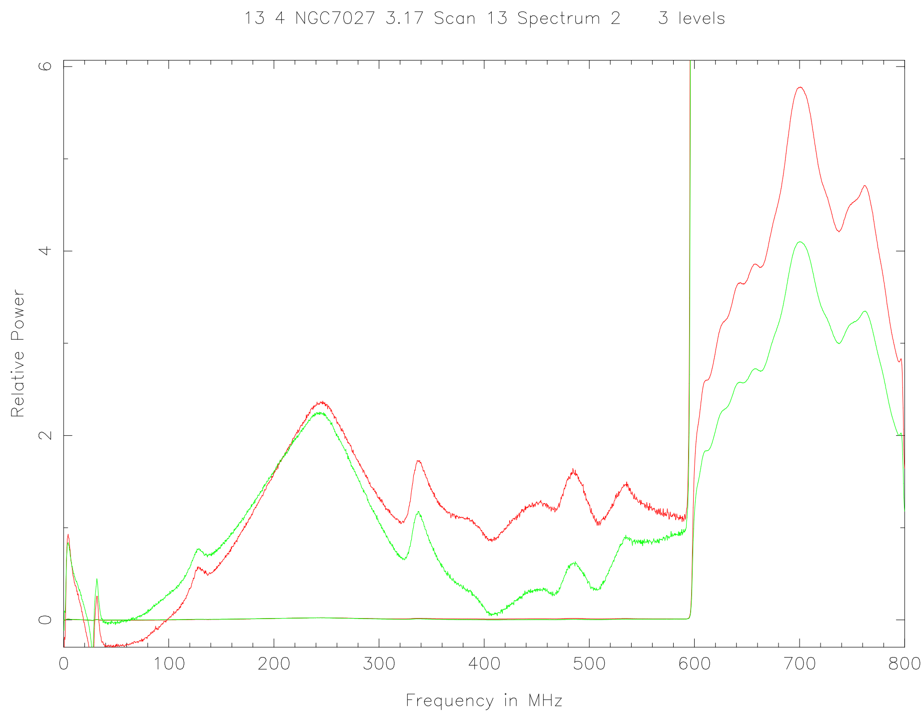

Figure 14: Scans 13-14: On and off total power spectra for the continuum source NGC 7027 using spectrometer bank D input J8 and a 200 MHz anti-alias filter in the analog filter module. The red trace is the on-source spectrum, and the green trace is off source. In the 0-600 MHz stop-band the spectra are replotted with 100 times the vertical scale.