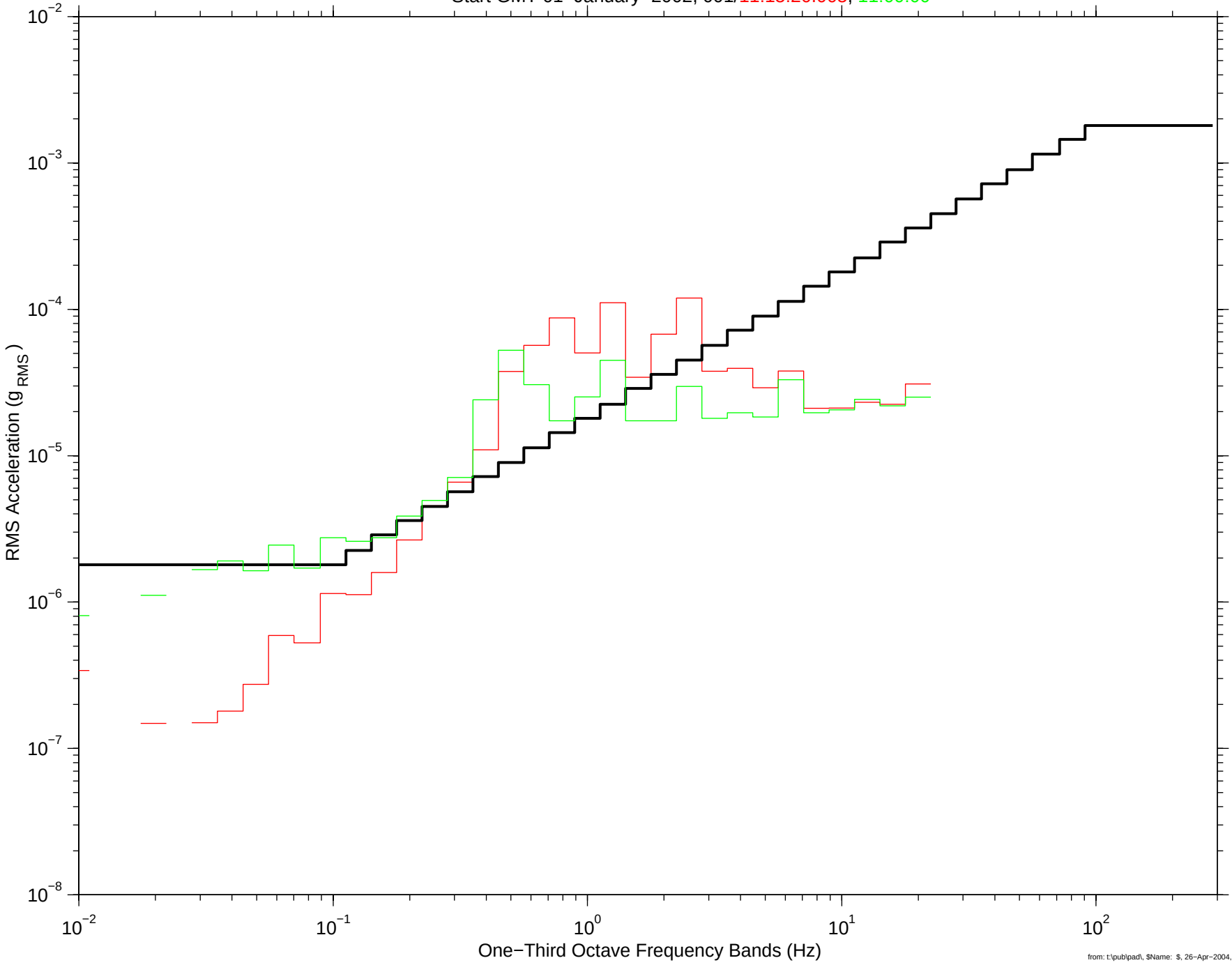
sams2, 121f05 at LAB1O1, ER2, Upper Z Panel:[185.17 38.55 149.93]
62.5000 sa/sec (25.00 Hz)
Δf = 0.008 Hz, Nfft = 8192
Mode: 100sec

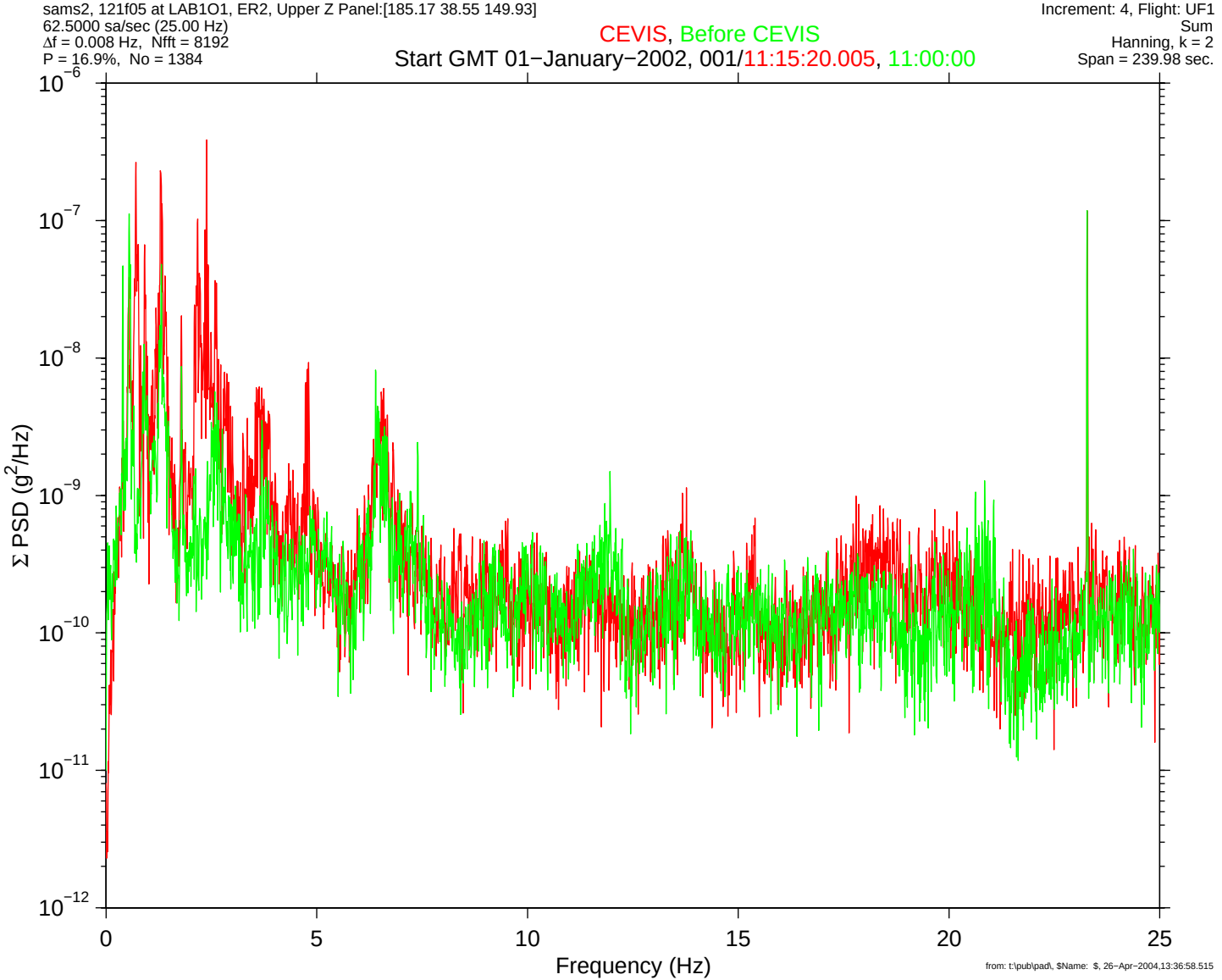
Increment: 4, Flight: UF1
Sum
Hanning, k = 5
Span = 239.98 sec.

CEVIS, Before CEVIS

Start GMT 01−January−2002, 001/11:15:20.005, 11:00:00



from: t:\pub\pad\, $Name: $, 26−Apr−2004,13:51:58.875


sams2, 121f05 at LAB1O1, ER2, Upper Z Panel:[185.17 38.55 149.93]
62.5000 sa/sec (25.00 Hz)
Δf = 0.008 Hz, Nfft = 8192
P = 16.9%, No = 1384
CEVIS, Before CEVIS
Start GMT 01−January−2002, 001/11:15:20.005, 11:00:00
Increment: 4, Flight: UF1
Sum
Hanning, k = 2
Span = 239.98 sec.
Σ PSD (g²/Hz)
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
0
5
10
15
20
25
Frequency (Hz)
from: t:\pub\pad\, $Name: $, 26−Apr−2004,13:36:58.515

This timeline was constructed based on video footage. Note that the exercise regimen calls for several different types of movement: squats, heel raises, deadlifts, and so on. The signature for these various movements is annotated in the spectrogram of Figure 6-209, which shows effects below 30 Hz. To quantify the acceleration impact of these motions below 30 Hz, the interval RMS plot of Figure 6-210 was computed. Interval RMS computations similar to these for the same period, but now below 10 Hz (for comparison to historic acceleration data) for SAMS 121f02 data yield the results shown in Table 6-29.

TABLE 6-29 RMS ACCELERATIONS BELOW 10 HZ PRODUCED BY VARIOUS RED EXERCISES

Exercise Type	Maximum RMS Acceleration (μg_{RMS})	Dominant Spectral Peaks (Hz)
none (baseline)	60	
squats	301	0.75
heel raises	691	3
deep heel raises	336	1.2
one-leg squats	255	0.75
deadlifts	206	0.75
shoulder shrugs & situps	168	0.6, 1.2
bench press & bent rows	222	0.6, 1.2

Note that the heel raise motion, by far, transmits the largest accelerations from the Node 1 RED location to the SAMS 121f02 location in ER1 of the US Lab (LAB1O2). In reviewing the video, it was noted that there was a brief interruption in the exercise period. At about GMT 02-September-2002, 245/09:33:12, FE-1 quickly soared out of Node 1 through the hatch toward the US Lab. Correlation with SAMS 121f02 measurements showed that this produced a peak acceleration magnitude of 9.67 mg. When FE-1 returned and landed on the RED base plate, this produced an acceleration of 3.75 mg primarily aligned with the Z_A-axis.

Figure 6-211 shows the measurements made by SAMS 121f02 over a span of about 230 seconds early in the RED exercise period. The large excursions from baseline that occurred about every 45 seconds (the first starting at about the 30-second mark) were caused by heel raises. Figure 6-212 shows this same period, but lowpass filtered at 5 Hz. The black, vertical dashed lines shown on the Z-axis bound a set of squats and heel raises. Note the lower magnitude, lower frequency impact of squats relative to the higher frequency heel raises. To show this more clearly, Figure 6-213 was produced for a zoom in around the times indicated by the black dash lines of Figure 6-212.

6.2.4.1.3 Cycle Ergometer with Vibration Isolation System (CEVIS)

The CEVIS is used for systemic aerobic conditioning and can be used to perform independent upper and lower limb cycle activity. CEVIS is located in the US Lab. Similar to TVIS, CEVIS isolates x, y, and z translation, roll, pitch, and yaw [6].

Based on a large volume of acceleration data from various Shuttle microgravity missions, experience has shown that individual crew vigor was a fundamental factor on the impact of ergometer exercise. Naturally, the more vigorous the individual exercised, the more pronounced

was the impact. The intent is not to track just how energetic various crew were during CEVIS exercise, but consideration of this factor may prove useful at some point in the future. Proximity of the CEVIS (US LAB Port 3 (LAB1P3)) to ER1 (LAB1O2) and ER2 (LAB1O1) make it a candidate for propagating oscillatory disturbances from its mounting location to the vibratory sensors in the nearby EXPRESS racks (see Figure 6-214). Two time spans that include CEVIS exercise were analyzed to characterize the measured effects at various accelerometer locations. These particular periods were considered for two reasons, they both: (1) exhibit ergometer acceleration signature based on experience from Shuttle ergometer exercise, and (2) correlate well with exercise data collected independently of the accelerometers. The correlating data came in the form of spreadsheet files recorded on PCMCIA cards for TVIS and CEVIS with all personal or sensitive information having been filtered out on the ground at the JSC.

For the first exercise period analyzed, the spectrogram in Figure 6-215 clearly shows an ergometer signature (as marked near bottom right), starting just before GMT 01-January-2002, 001/11:13:34. The spreadsheet, on the other hand, shows a start time of GMT 01-January-2002, 001/11:13:11. Part of this roughly 20-second lag is attributable to the temporal resolution used to compute the spectrogram, which was 4.096 seconds. The spectrogram's end time truncates the exercise period because this time marks the beginning of a PIMS Acceleration Data (PAD) gap. Meanwhile, the spreadsheet indicates that the exercise was completed at about 11:23, and therefore lasted about 10 minutes. The narrowband peak at about 2.5 Hz marked on the lower right of the spectrogram is the pedaling frequency. For Shuttle ergometer exercise, the pedaling signature was accompanied by that of shoulder sway with frequency around half the pedal rate. On the ISS for this CEVIS exercise period, the shoulder sway signature is obscured by structural modes that fall in the same frequency range. Figure 6-215 qualifies the exercise regime from the 121f05 sensor location atop ER2. To quantify the impact of this exercise period from this and other sensor locations, the cumulative RMS acceleration versus frequency curves of Figure 6-216 were computed. The legend at the upper left shows which trace was computed for each of 4 different sensors. The curves in this figure all step up about 70 μg_{RMS} at the pedaling frequency, but vary to some degree across the rest of the acceleration spectrum below 10 Hz. The variability is expected as the SAMS sensors used for the analysis were distributed throughout ER1 and ER2 as indicated by the legend.

The second CEVIS exercise period analyzed is depicted in the spectrogram of Figure 6-217. Note the frequency scale is zoomed below 15 Hz and the color scale is zoomed beyond nominal settings. Close examination with these zoom settings, gives clear indication of ergometer pedal signatures in the dashed boxes. Again shoulder sway is hard to detect in the midst of structural modes around 1 Hz. The spreadsheet file for this time frame shows a CEVIS exercise from GMT 03-January-2002, 003/10:24:41 to 10:30:26 and therefore lasting slightly less than 6 minutes. These times corresponds closely with the later of the 2 pedal signatures in the right dashed box. An earlier exercise period (the left dashed box) was likely that from a different crew member. To quantify the impact of the earlier CEVIS period from this and other sensor locations, the cumulative RMS acceleration versus frequency curves of Figure 6-218 were computed. The legend at the upper left shows which trace was computed for each of 5 different sensors. The curves in this figure show this exercise period to be much quieter than the one quantified above for GMT 01-January-2002. Each curve steps less than about 2 μg_{RMS} at the pedaling frequency of nearly 2.8 Hz. Similar analysis for the later CEVIS period marked in

Figure 6-217 produced the curves in Figure 6-219. Again only minimal impact was registered at the pedaling frequency near 2.8 Hz. Also, note for the cyan curves of Figure 6-218 and Figure 6-219, the 121f06 sensor was mounted inside the ARIS ER2.

6.2.4.1.4 Russian Velosiped (VELO)

Perusal of roadmap spectrograms for GMT 25-July-2002 to 31-July-2002 shows what is most certainly the signature of daily VELO exercise for a couple of hours around noon and again around 18:00 (see below 5 Hz on and Figure 6-220 and Figure 6-221 and compare with highlighted times in excerpts of the short-term plan for that day shown in Figure 6-222 and Figure 6-223, respectively).

To quantify the impact of VELO exercise, consider the 10-minute span starting at GMT 31-July-2002, 212/12:50:00. A cumulative RMS acceleration versus frequency curve for 4 different SAMS sensors were computed and the results shown in Figure 6-224. A sharp step up at the pedal rate of about 2.2 Hz is evident in these curves along with smaller step at shoulder sway frequency. This marks a difference for VELO from CEVIS. The shoulder sway frequency is pronounced for VELO exercise. A more complete quantification for this pedal rate frequency can be seen in the 8-second interval RMS acceleration plot of Figure 6-225. The RMS acceleration was computed for the frequency range from 2.1 to 2.3 Hz. To the right of the 12:00 time tick, just before 13:00, there is the 10-minute period referenced above. This shows a step up from a baseline of about 2 μg_{RMS} without VELO to between 50 and 100 μg_{RMS} when VELO is being used. This step up from baseline occurs again around the 18:00 mark, which is when we see the VELO signature again below 5 Hz in Figure 6-221.

Short-term plans and roadmap spectrograms agree that more VELO exercise occurred around GMT 06-August-2002, 218/17:00:00 and lasted until about 18:45 (see Figure 6-226 for example). To measure the impact of this VELO exercise, Figure 6-227, Figure 6-228, Figure 6-229, and Figure 6-230 were generated to show the 8-second interval RMS accelerations below 5 Hz. For all these SAMS sensor locations, the sub 5 Hz RMS level was well below 100 μg_{RMS} when no VELO exercise took place, but often was in excess of 150 μg_{RMS} during the exercise.

A final VELO exercise period for analysis took place at around GMT 07-August-2002, 219/11:00. For comparison to the results for CEVIS exercise in Section 6.2.4.1.3, consider a 1-minute snapshot of the VELO period starting at GMT 07-August-2002, 219/11:12:45. Computation of cumulative RMS acceleration versus frequency curves for SAMS sensors in ER1 and ER2 yields the plot in Figure 6-231. From this figure, first note that the RMS scale for these curves is an order of magnitude greater than similar plots discussed earlier for CEVIS exercise. Also, note the pedal spectral peak for this snapshot was at about 2.3 Hz and produced a step of nearly 200 μg_{RMS}. Meanwhile, at the shoulder sway spectral peak (about 1.15 Hz), there was a step of over 50 μg_{RMS}. The data for the 121f02 SAMS sensor was considered for inclusion in this analysis, but rejected because of a transient during the 1-minute span of interest. CEVIS and VELO are similar devices, with exception of the vibration isolation afforded by the CEVIS. It is seen from this final comparison between CEVIS (located in the US Lab, relatively close to SAMS sensors) and VELO (located in the Service Module) exercise that the isolation provided by CEVIS results in far less of a vibratory acceleration impact.

Figure 6-214 Digital Image of CEVIS Exercise

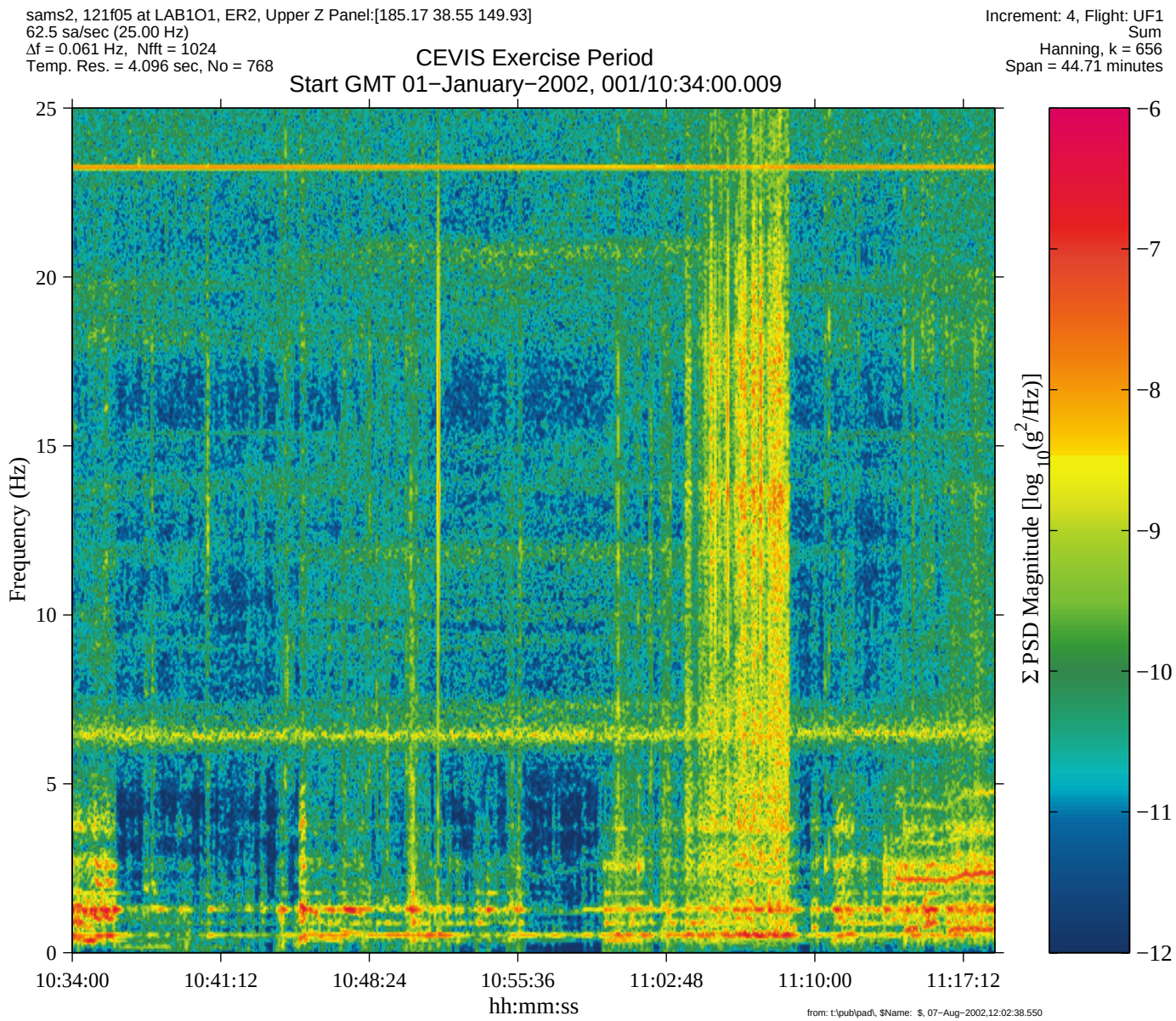


Figure 6-215 Spectrogram of CEVIS Exercise Period (121f05)

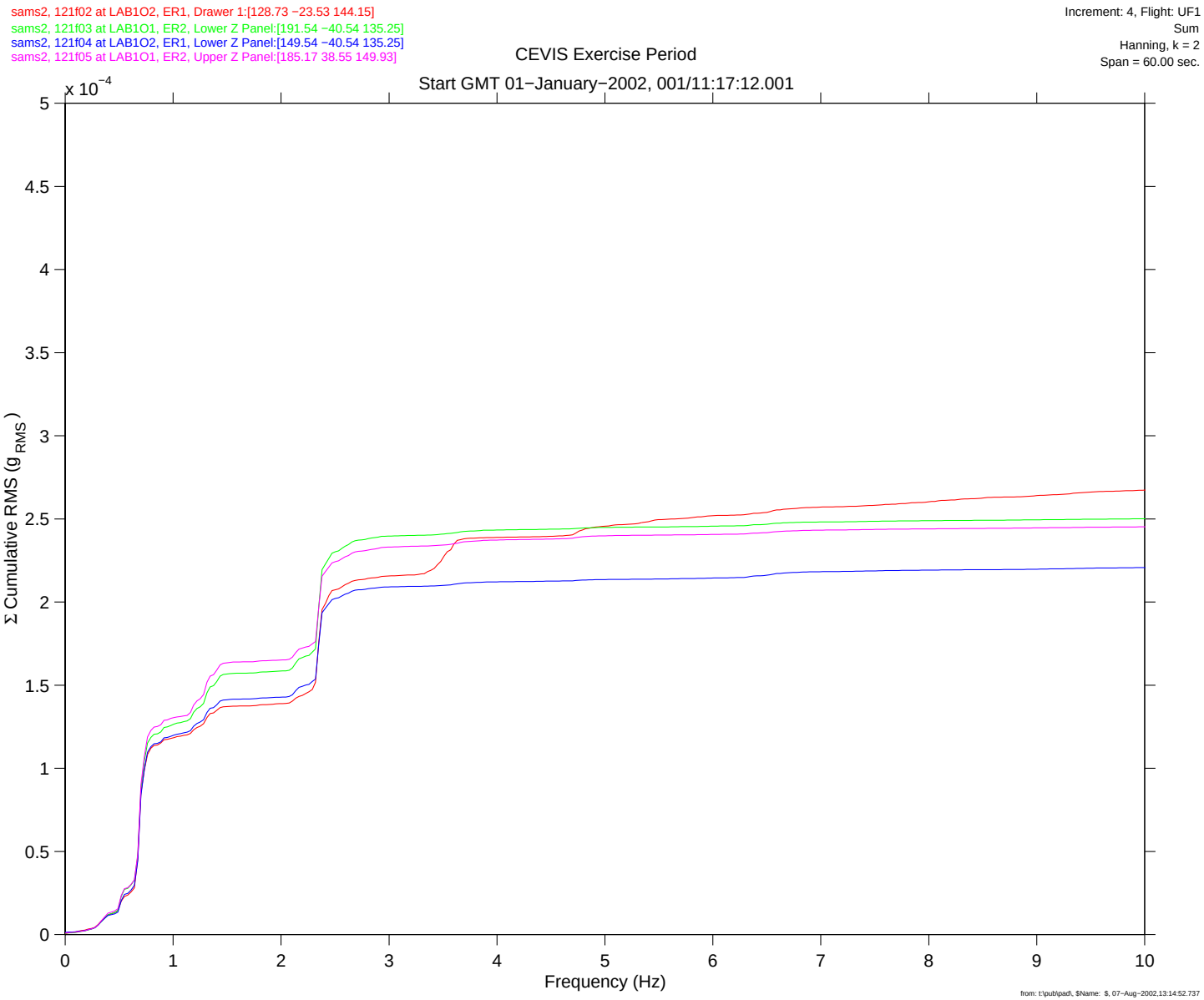


Figure 6-216 Cumulative RMS of CEVIS Exercise Period (121f02, 121f03, 121f04, 121f05)

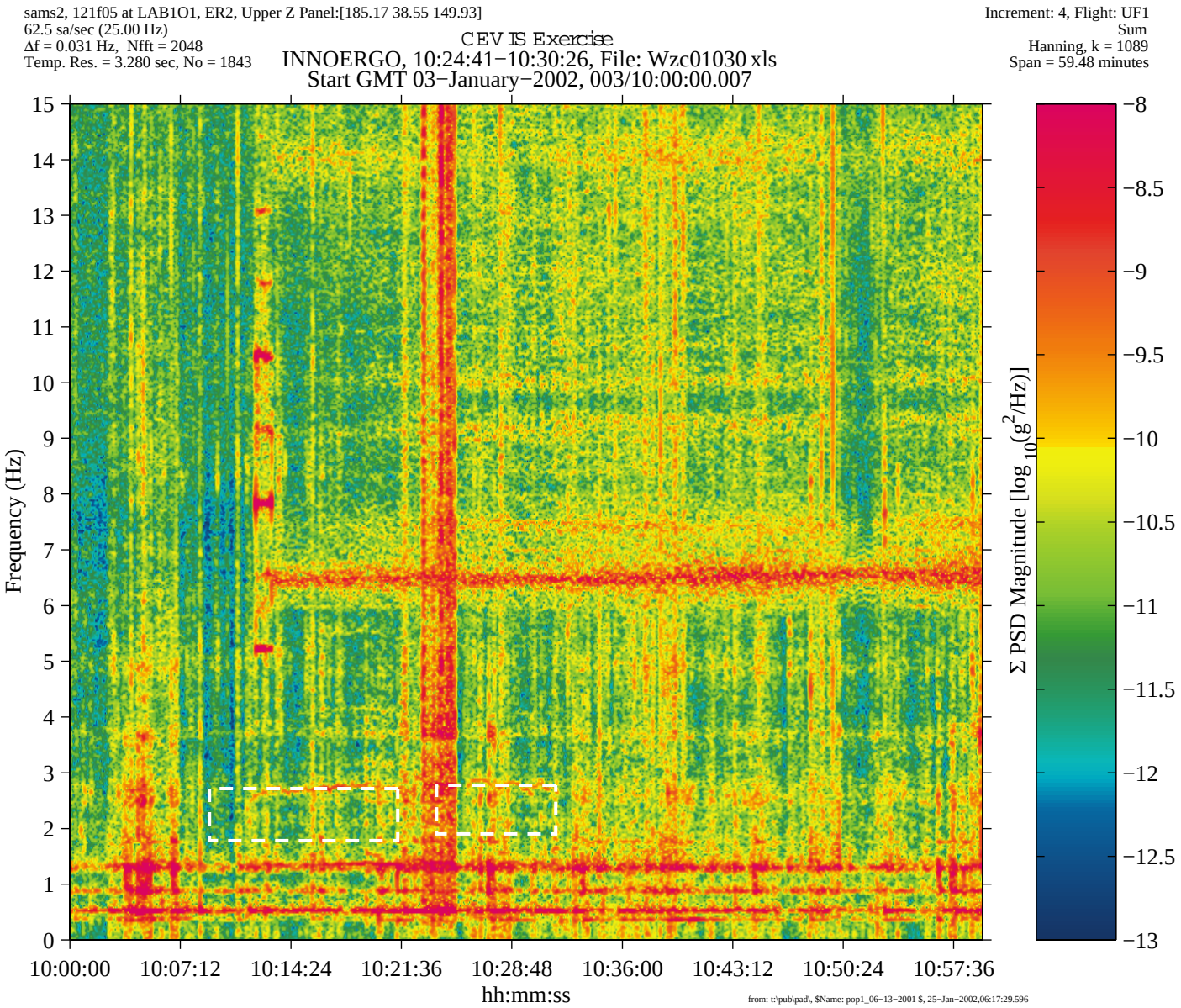


Figure 6-217 Spectrogram of CEVIS Exercise Period (121f05)

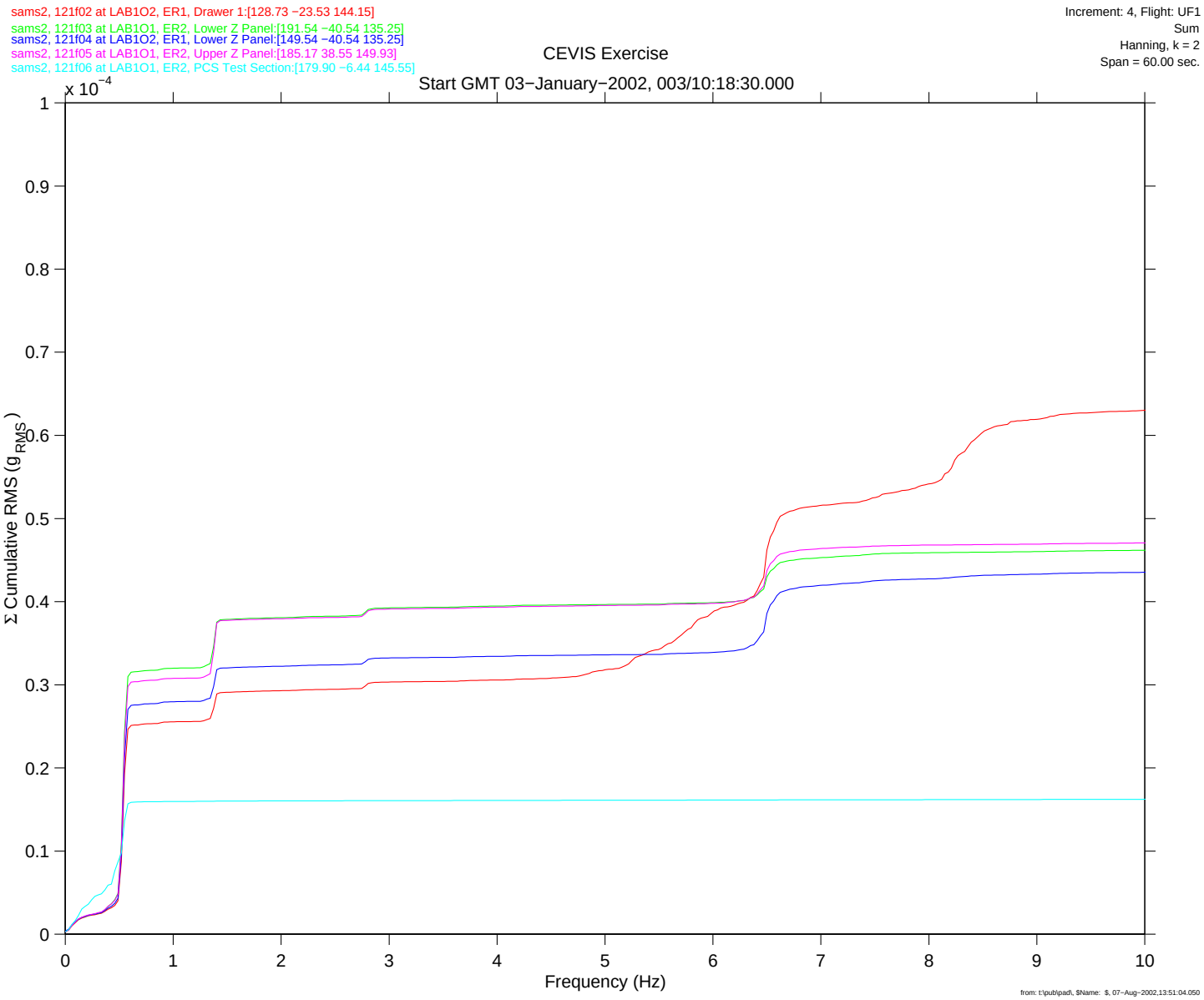


Figure 6-218 Cumulative RMS of CEVIS Exercise Period (121f02, 121f03, 121f04, 121f05)

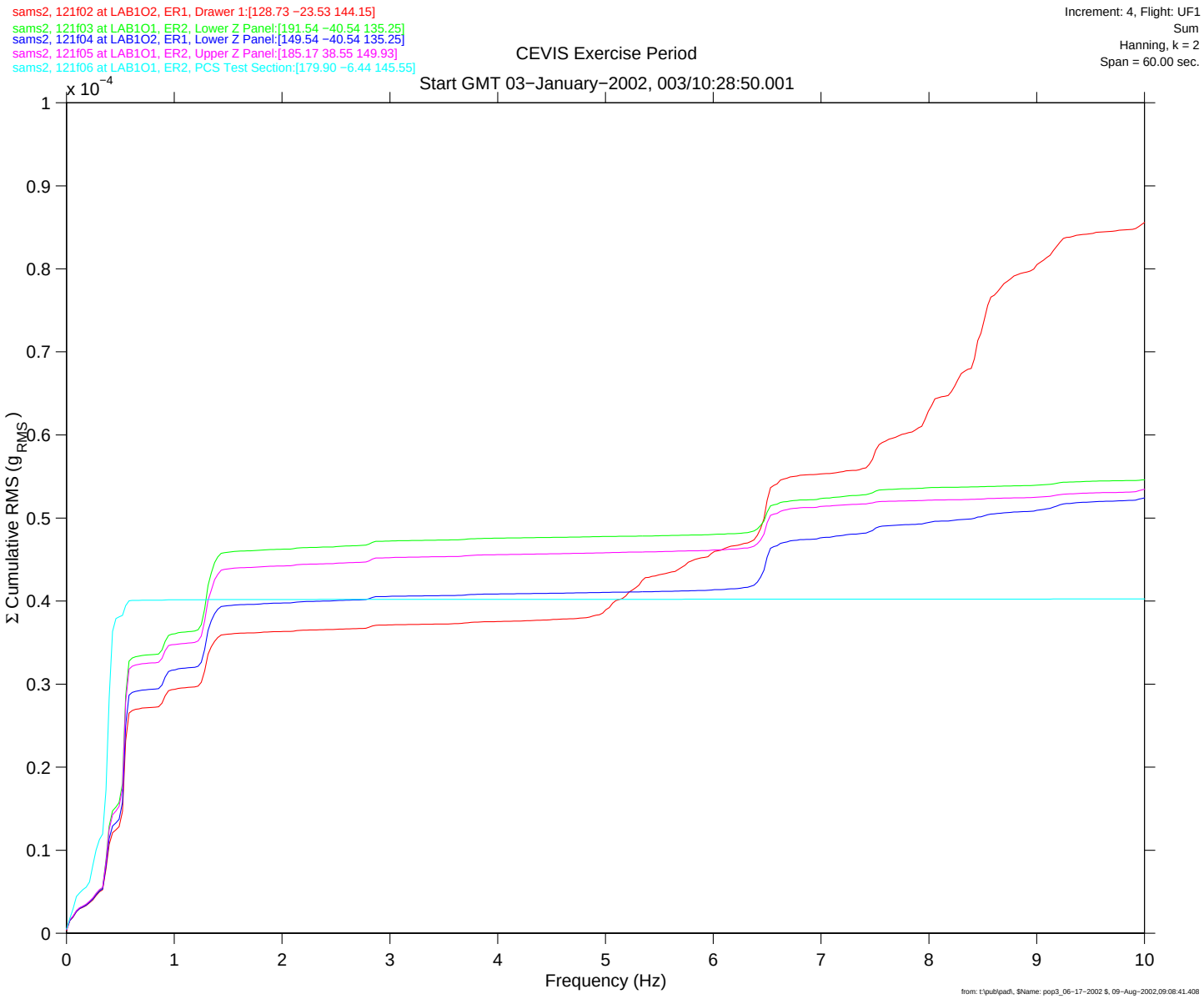


Figure 6-219 Cumulative RMS of CEVIS Exercise Period (121f02, 121f03, 121f04, 121f05)