

1. INTRODUCTION

A commercial service offered by the European Space Agency (ESA) is allowing researchers, educators, universities and companies to conduct their experiments on the International Space Station (ISS). The new facility is called ICE Cubes, and a wide range of microgravity researchers can build their experiment in modular blocks (cubes) of 10x10x10 cm that will slot into a dedicated rack within ESA's laboratory, the Columbus module, aboard the space station. Similar to small CubeSats that orbit Earth, ICE Cube experiments can be made from commercial off-the-shelf products and be stacked together to allow for larger experiments within the payload volume. These modules were designed with an eye on modularity, which allows ICE Cubes projects to plug-and-play, and be readied for flight more rapidly compared to traditional space experiment schedules. Figure 1 shows a mockup of the ICE Cubes facility.



Fig. 1: Mockup of ICE Cubes facility.

During crew sleep hours on May 28-29 of 2019, ICE Cubes operators stepped the facility fan speed through duty cycles ranging from 0% to 100%, thereby stepping the fan across numerous operating speeds in an effort to characterize and quantify

the vibratory impact on the local microgravity environment within the Columbus module.

2. QUALIFY

The Space Acceleration Measurement System (SAMS) had a sensor (S/N 121f08) operating in the European Physiology Module (EPM), which is located at rack COL1A3, at the time of the ICE Cubes fan speed testing. The color spectrogram shown in Figure 2 on page 2 shows the distinctive vibratory stair-step result comprised of spectral components as indicated for the various duty cycle percentages (i.e. fan speeds) on the 28th of May, 2019. At certain speeds, we see evidence of upper harmonic components (in dashed ovals). Also, it is not obvious why the nominal duty cycle of 20% shows a narrowband signature at about 71 Hz (unless this is a 3rd harmonic and the fundamental is not apparent).

3. QUANTIFY

The one-third octave, root-mean-square (RMS) acceleration versus frequency plots shown in Figures 3 through 12 on pages 3 through 12, respectively, show a blue trace of the Columbus IRD Microgravity Limits curve overlaid on top of (black) values computed from SAMS measurements in the Columbus module on the 28th of May, 2019.

4. CONCLUSION

The vibratory impact of the ICE Cubes facility fan is well below the one-third octave frequency band RMS values enumerated in the Columbus Interface Requirements Document (IRD). As a side note, a fundamental difference between the ICE Cubes fan speed testing that was conducted in July 2018 and May 2019 was that the latter was done during crew sleep. This would expectedly show a quieter environment below about 6 Hz, which is not the domain of the fan's vibratory impact and therefore inconsequential, but does have bearing on comparisons to the IRD limits. For further details to compare with similar testing done during crew wake in July 2018, see the PDF file at [this link](#).

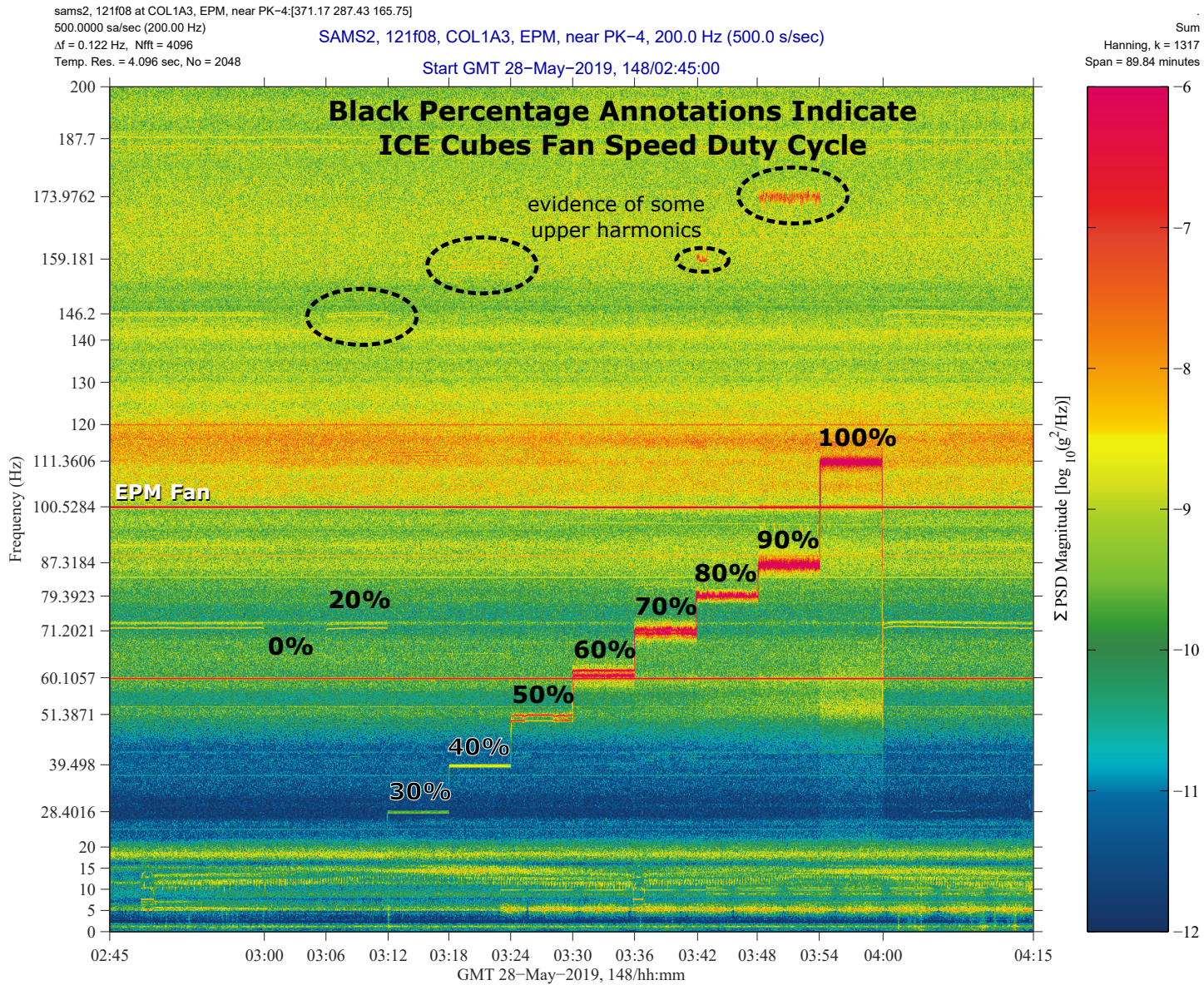


Fig. 2: Spectrogram Computed from SAMS Sensor on EPM Rack During ICE Cubes Fan Speed Test on GMT 28-May-2019.

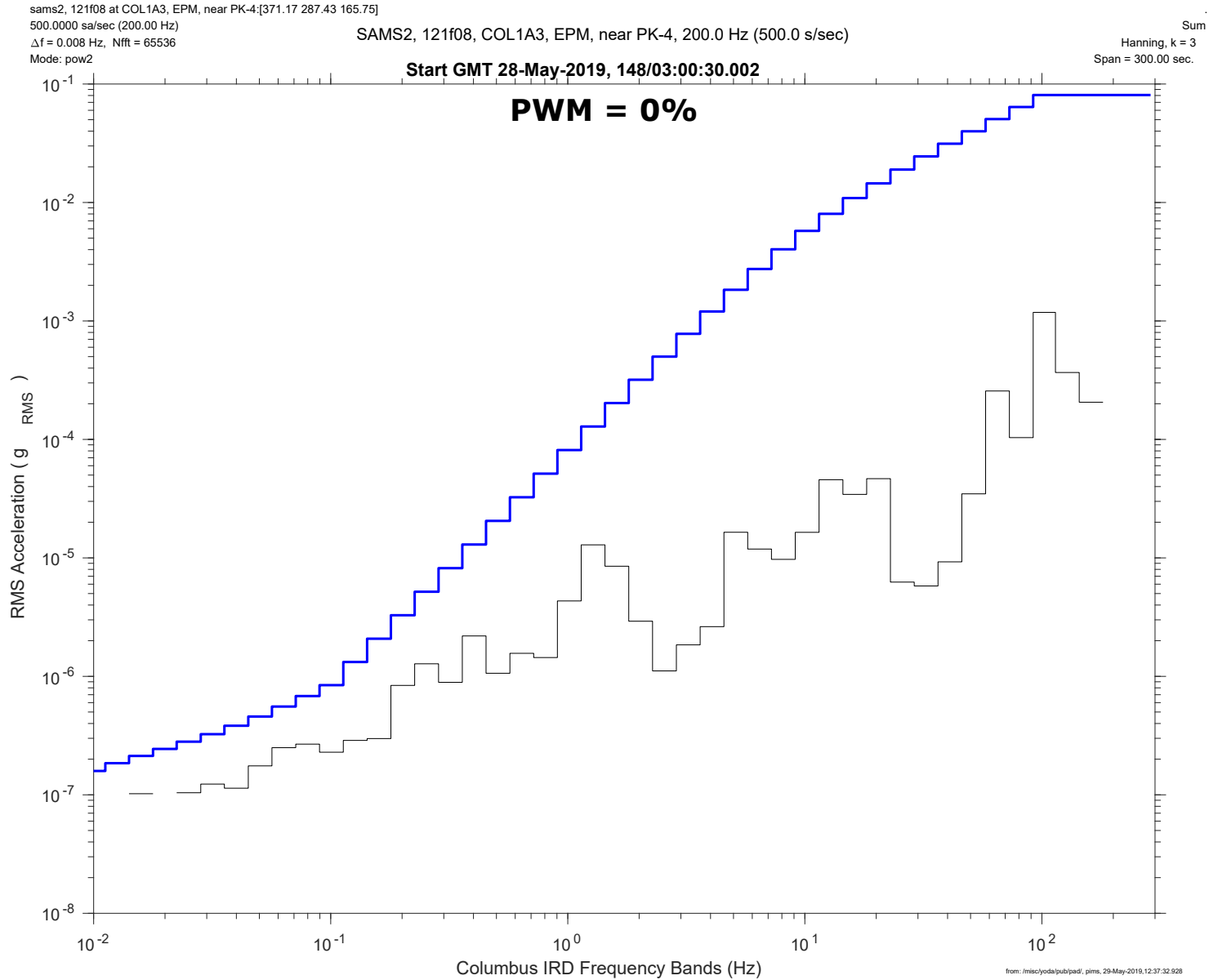


Fig. 3: One-Third Octave RMS Acceleration vs. Frequency (PWM = 0%).

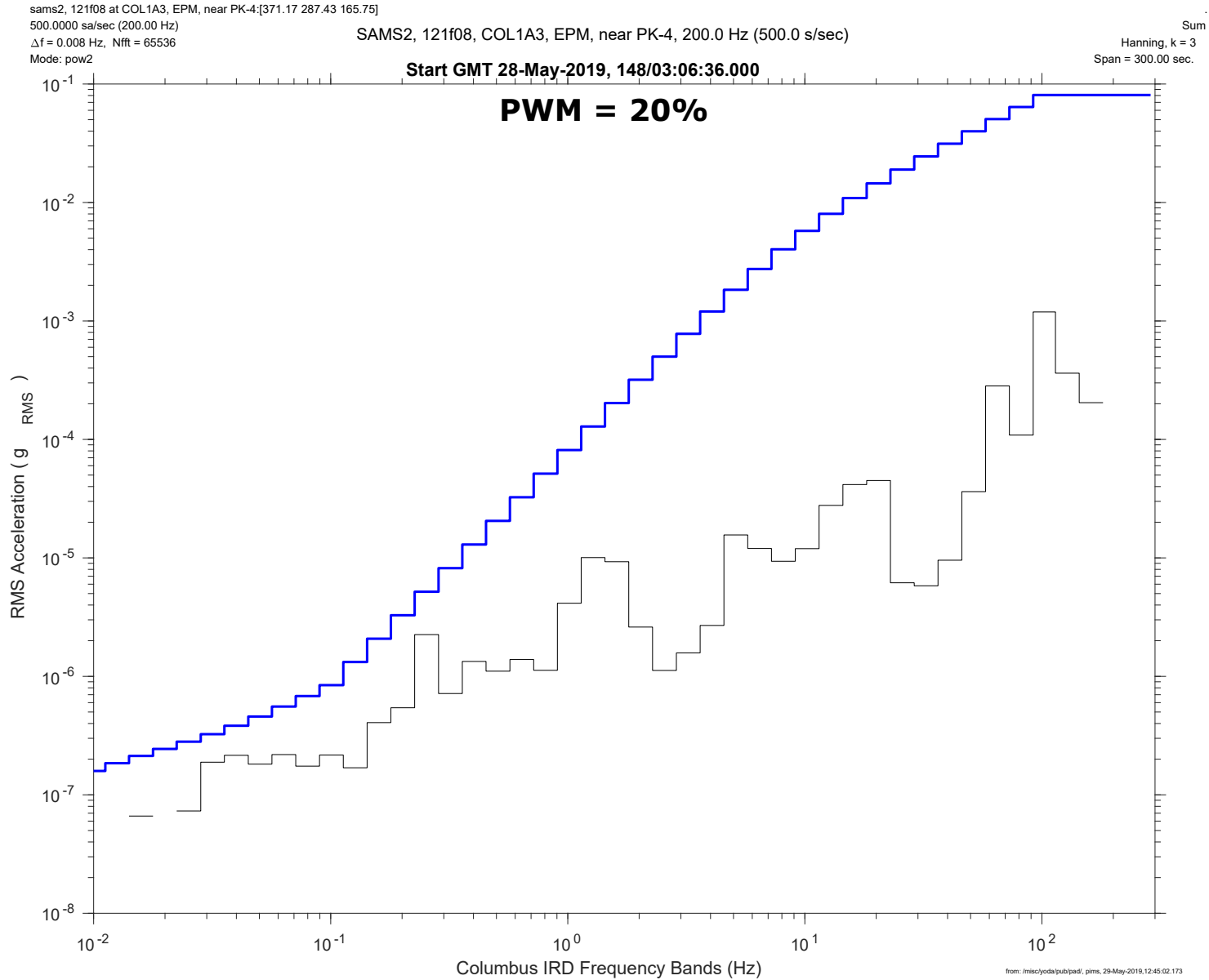


Fig. 4: One-Third Octave RMS Acceleration vs. Frequency (PWM = 20%).

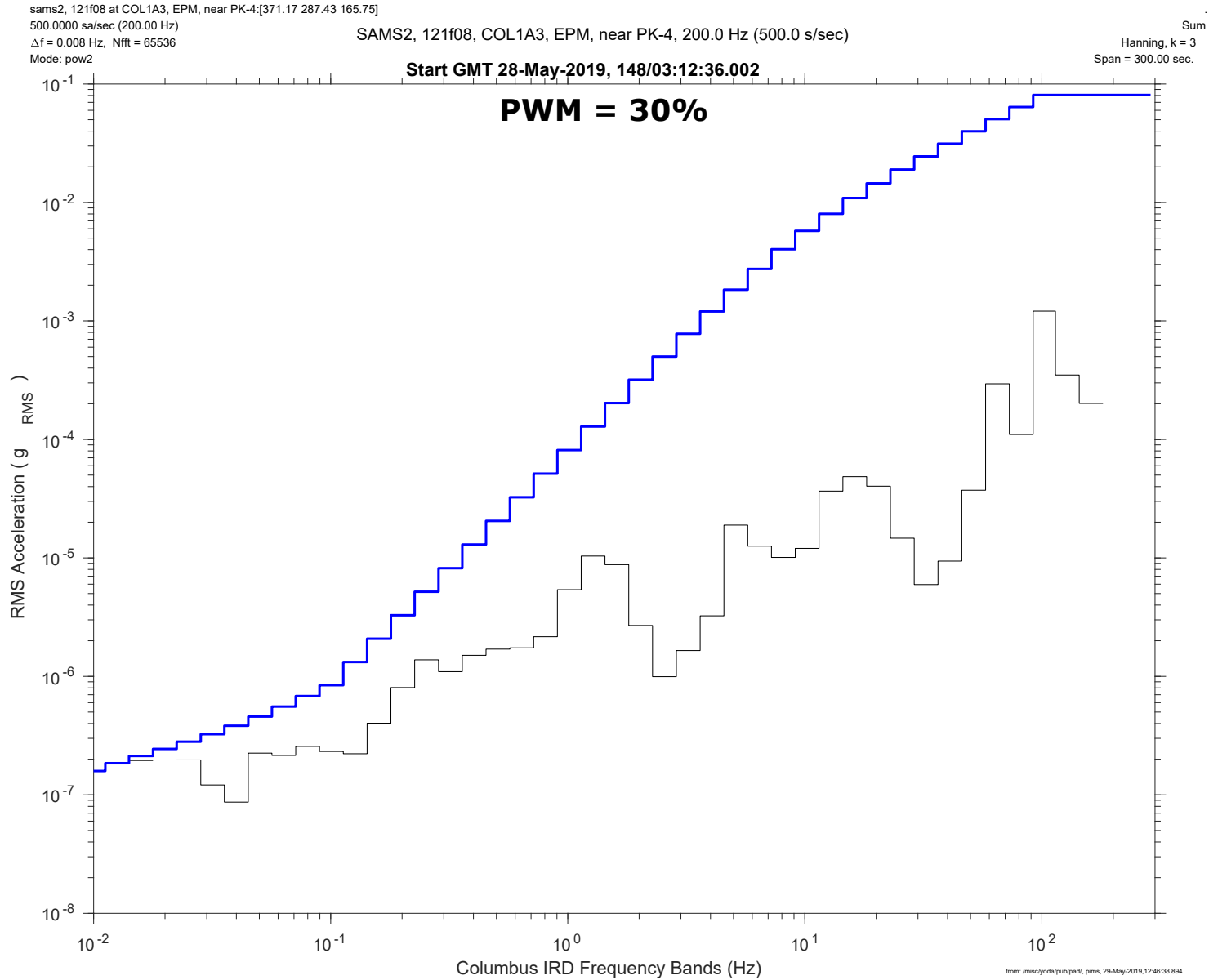


Fig. 5: One-Third Octave RMS Acceleration vs. Frequency (PWM = 30%).

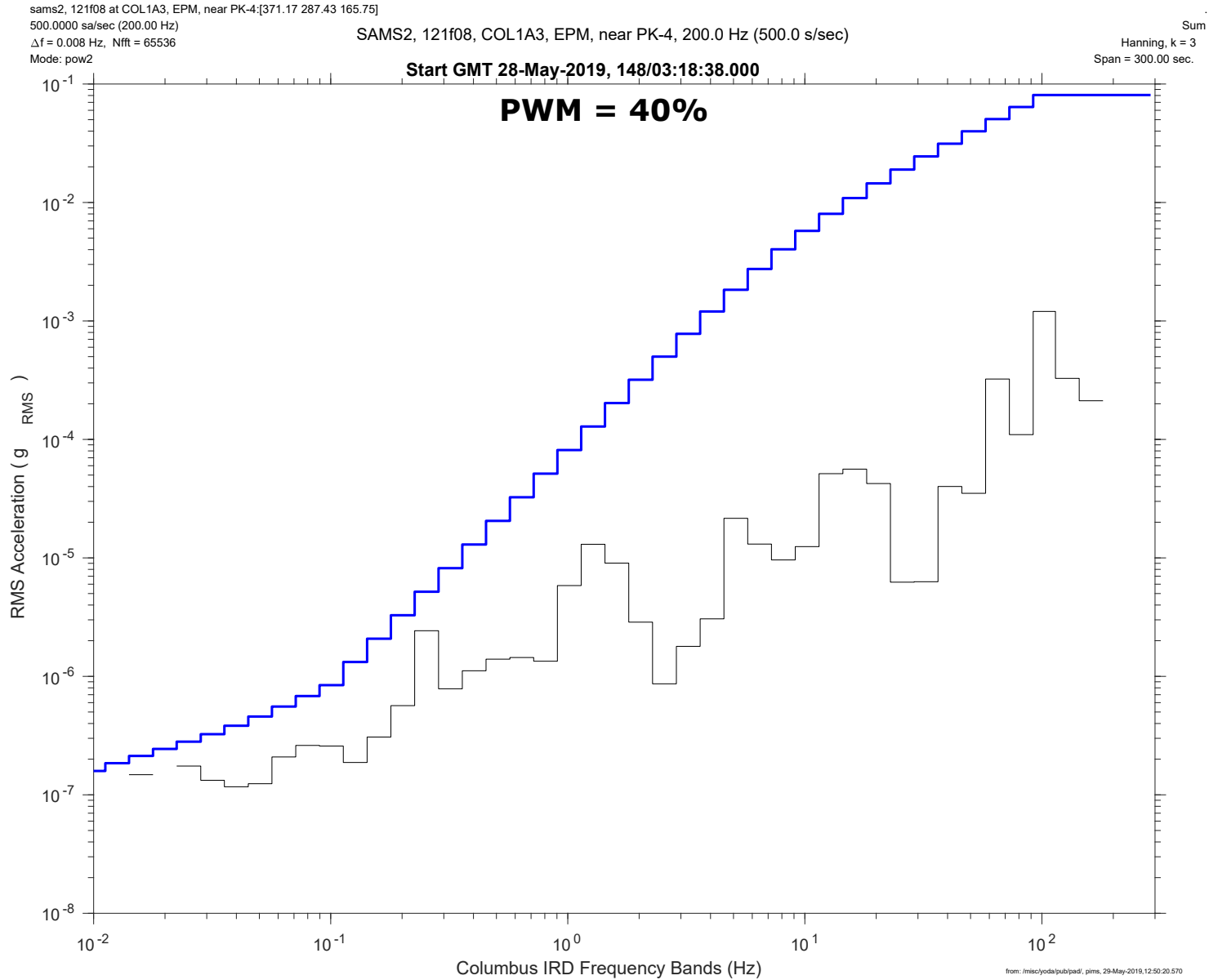


Fig. 6: One-Third Octave RMS Acceleration vs. Frequency (PWM = 40%).

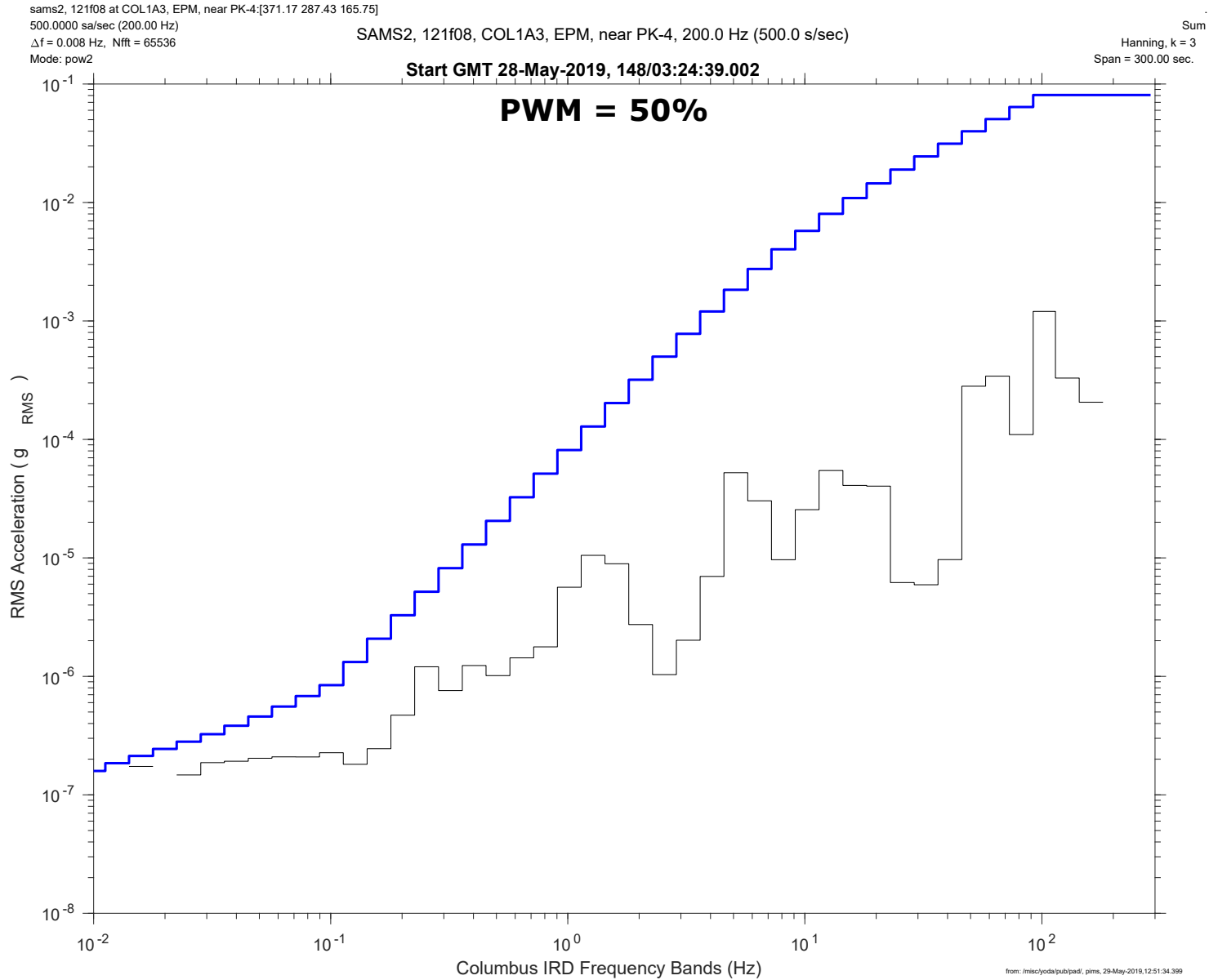


Fig. 7: One-Third Octave RMS Acceleration vs. Frequency (PWM = 50%).

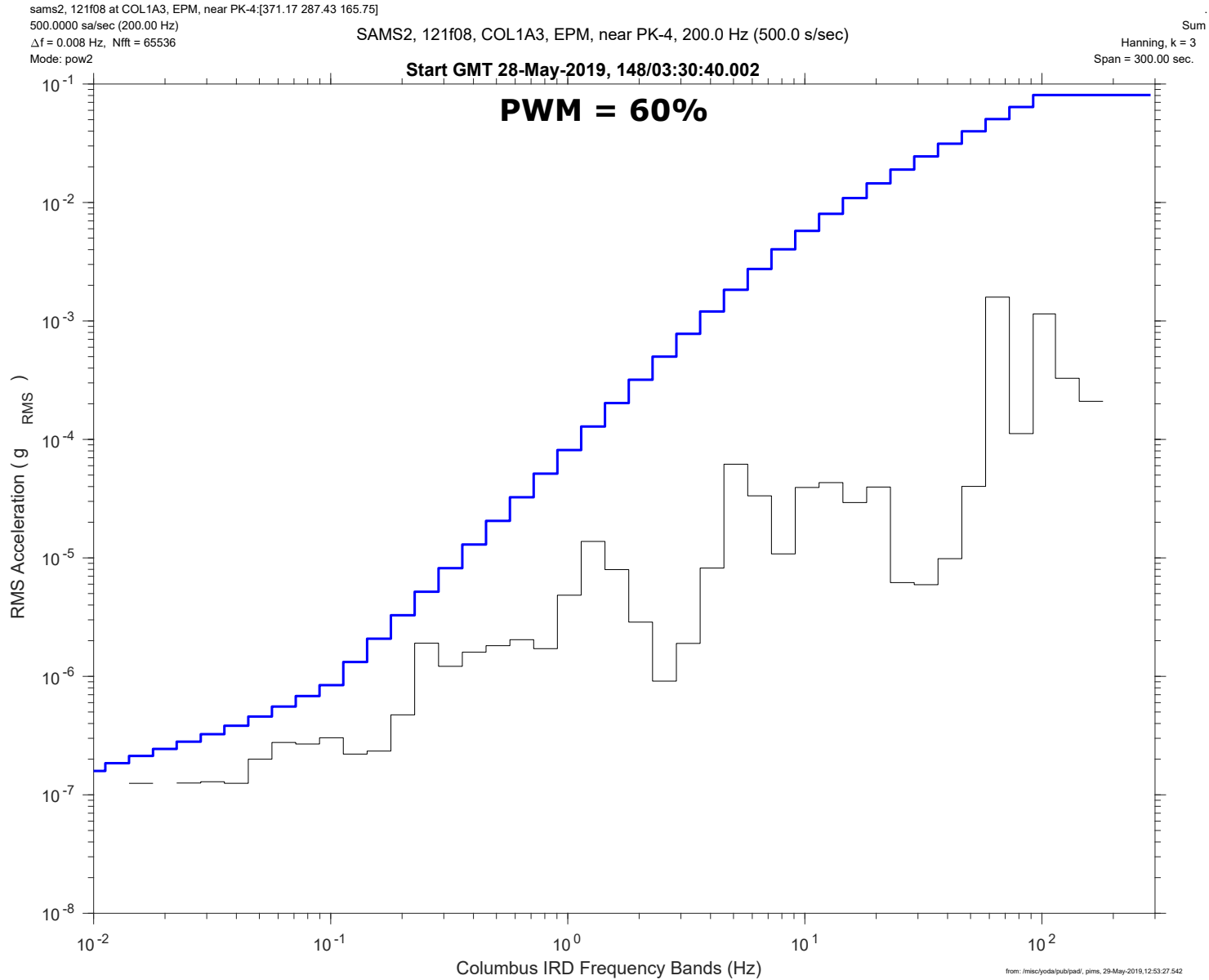


Fig. 8: One-Third Octave RMS Acceleration vs. Frequency (PWM = 60%).

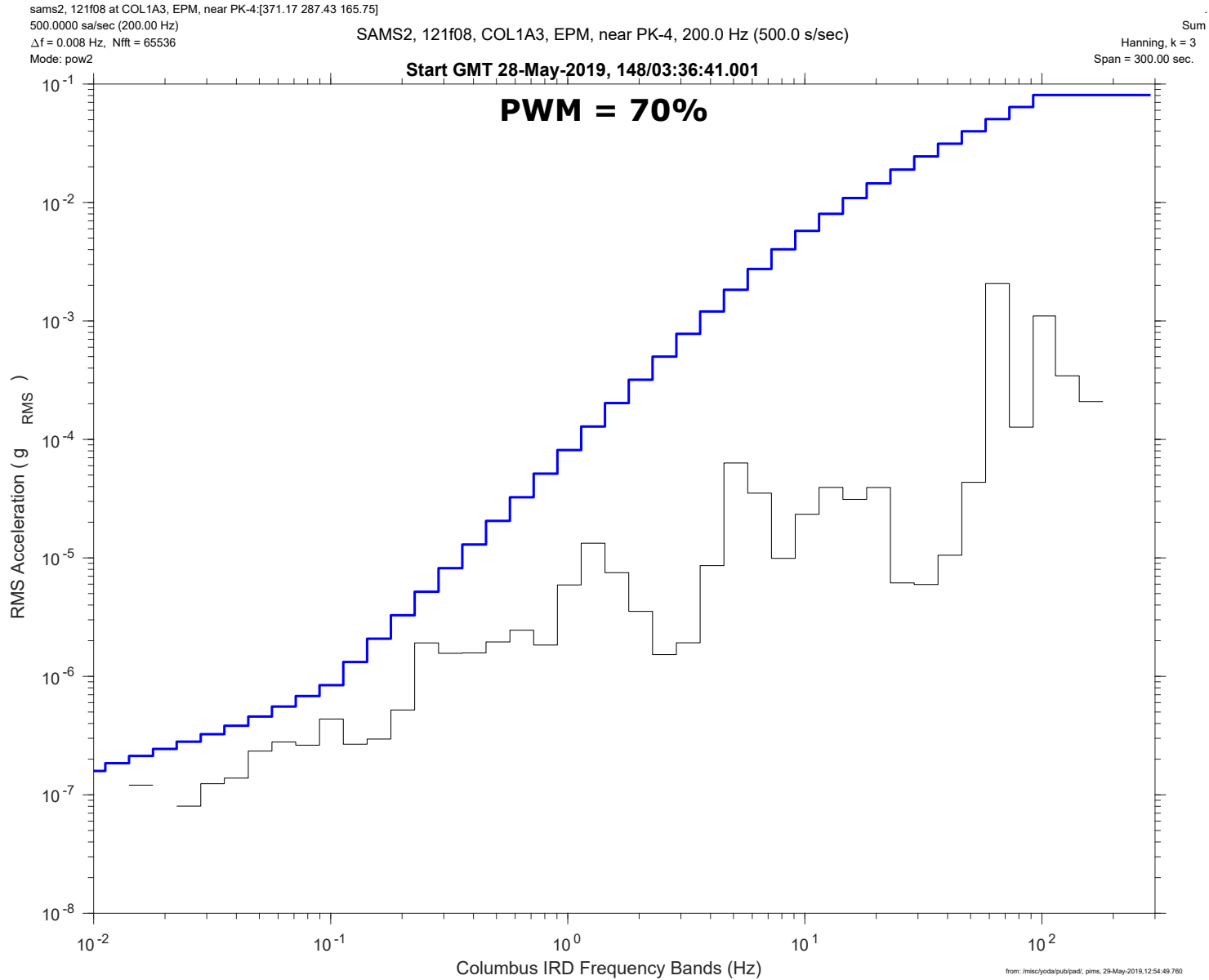


Fig. 9: One-Third Octave RMS Acceleration vs. Frequency (PWM = 70%).

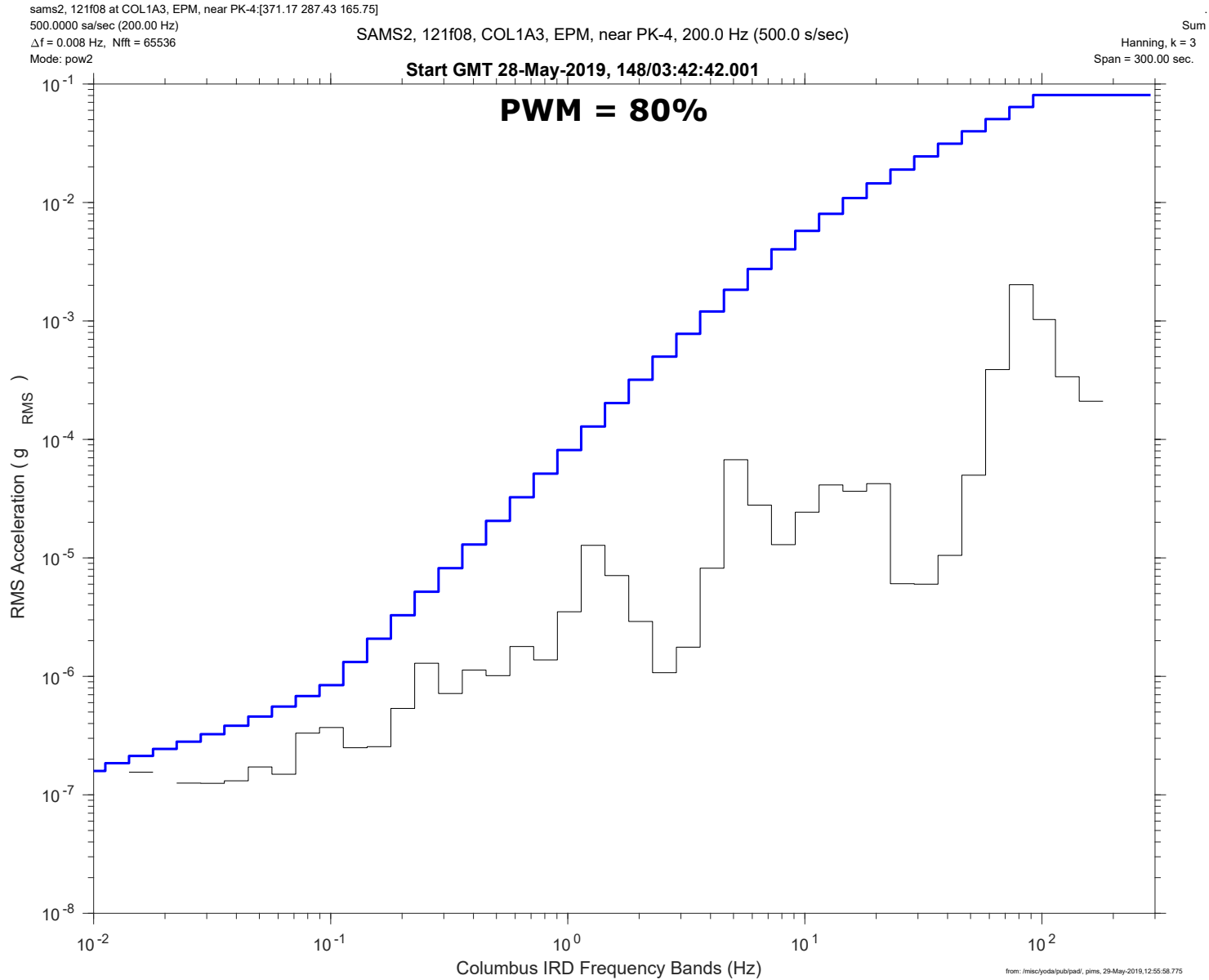


Fig. 10: One-Third Octave RMS Acceleration vs. Frequency (PWM = 80%).

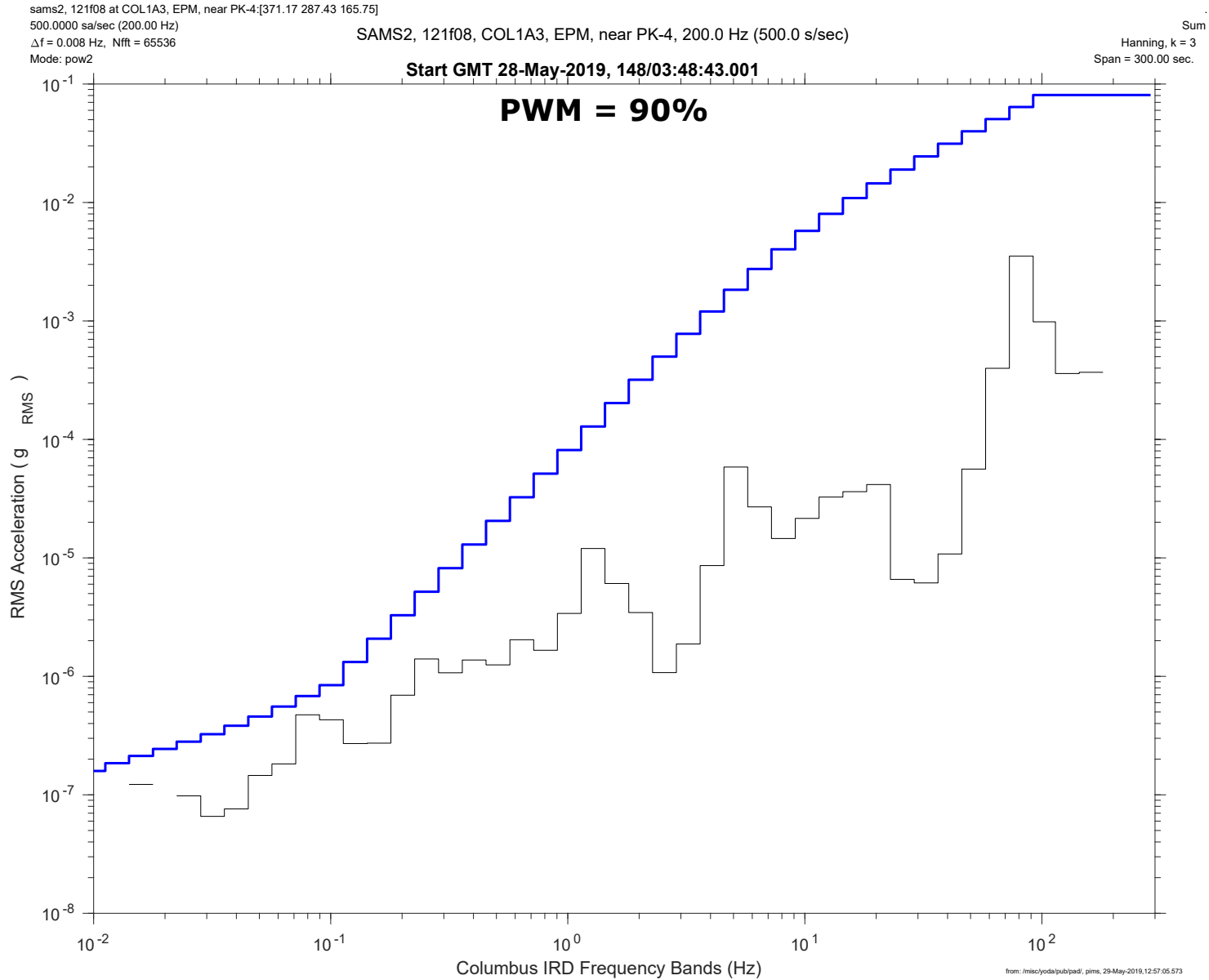


Fig. 11: One-Third Octave RMS Acceleration vs. Frequency (PWM = 90%).

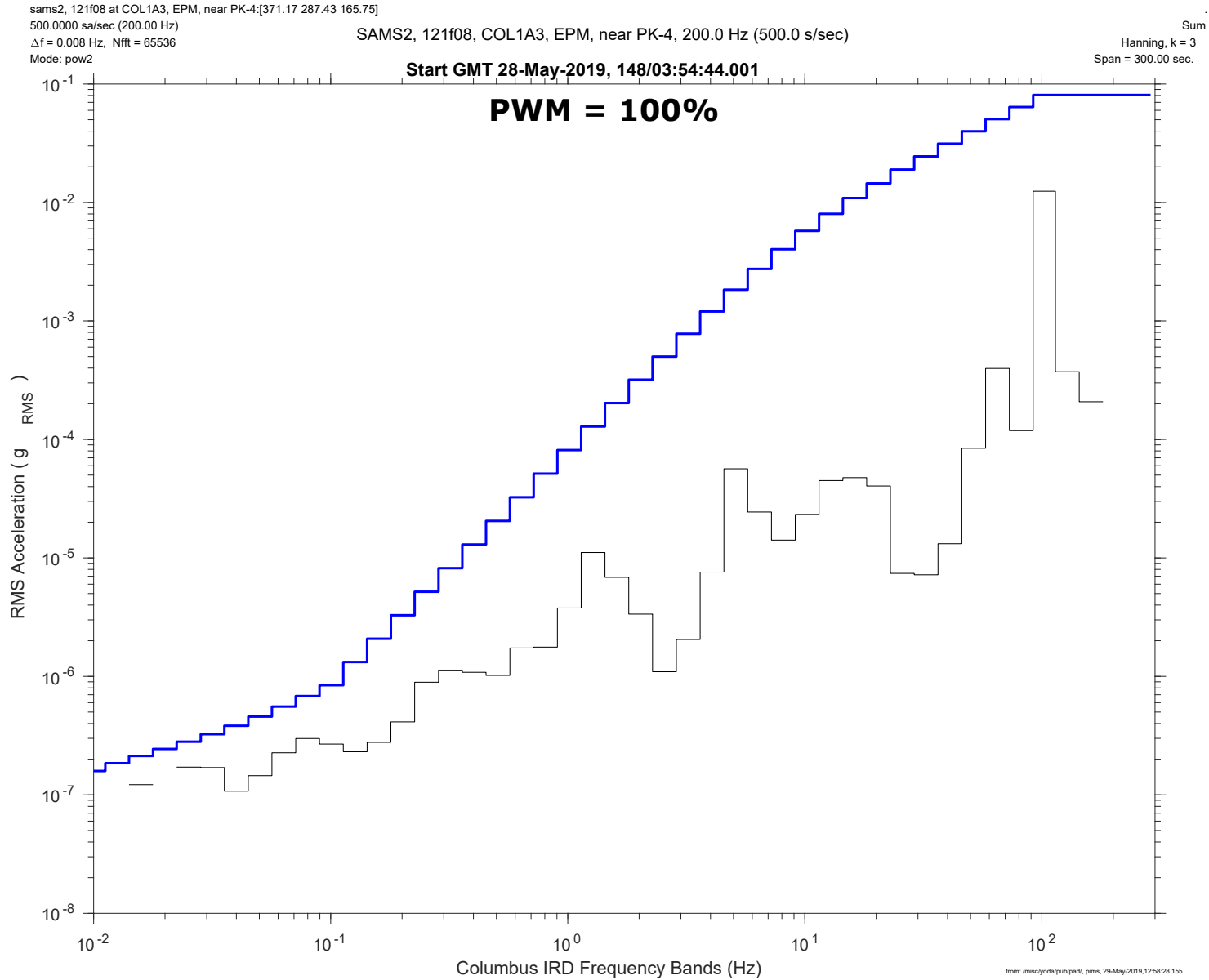


Fig. 12: One-Third Octave RMS Acceleration vs. Frequency (PWM = 100%).

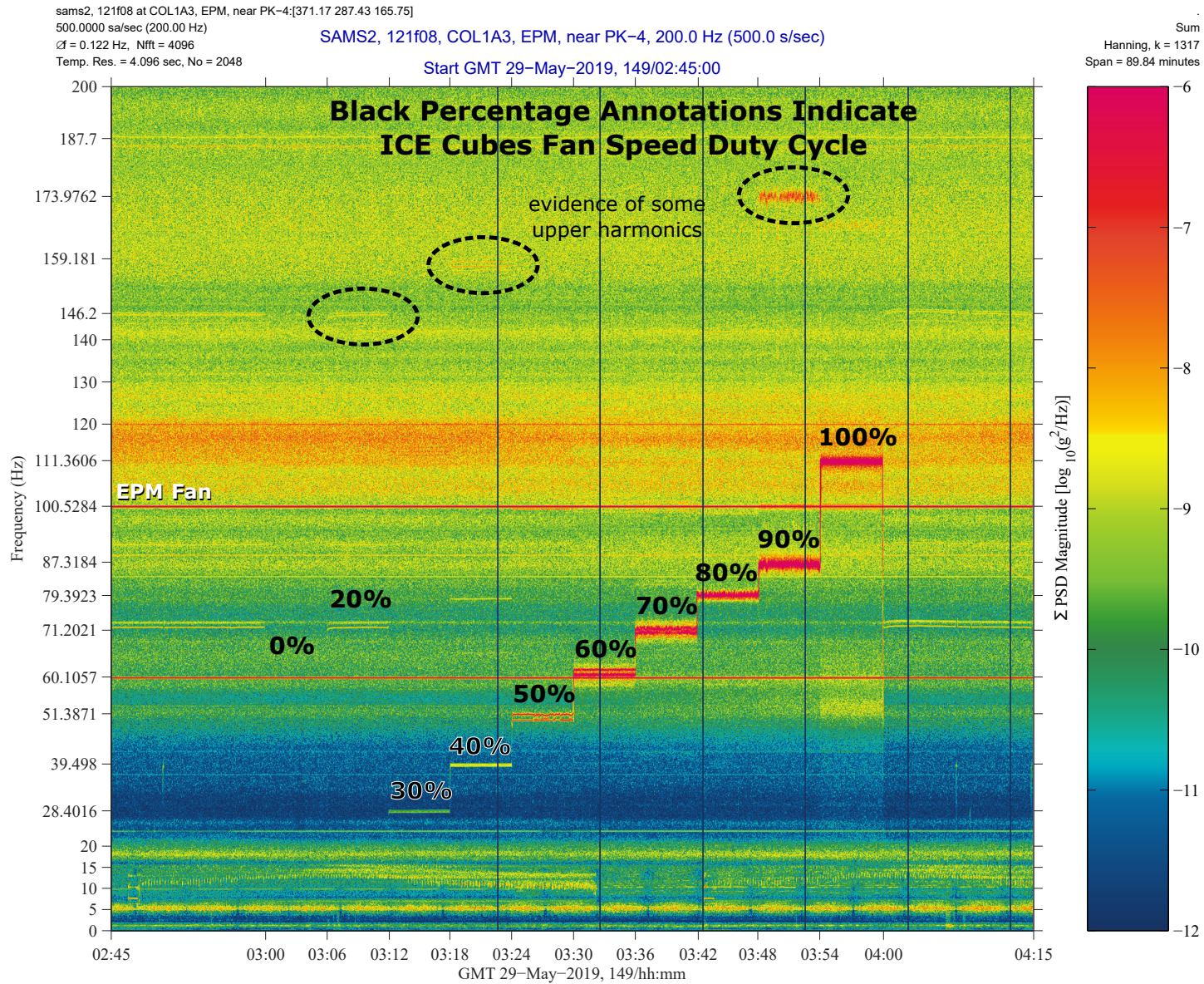


Fig. 13: Spectrogram Computed from SAMS Sensor on EPM Rack During ICE Cubes Fan Speed Test on GMT 29-May-2019.

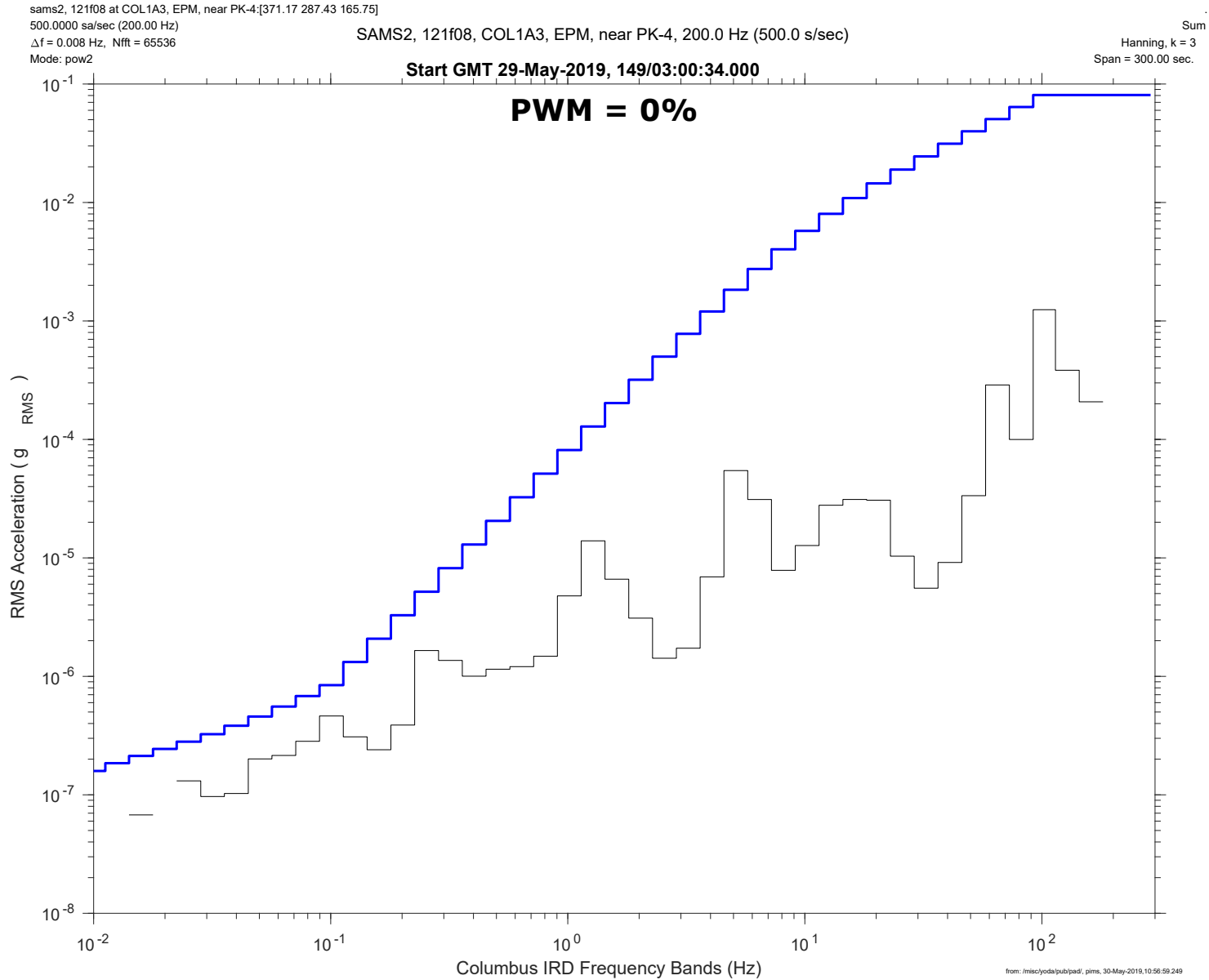


Fig. 14: One-Third Octave RMS Acceleration vs. Frequency (PWM = 0%).

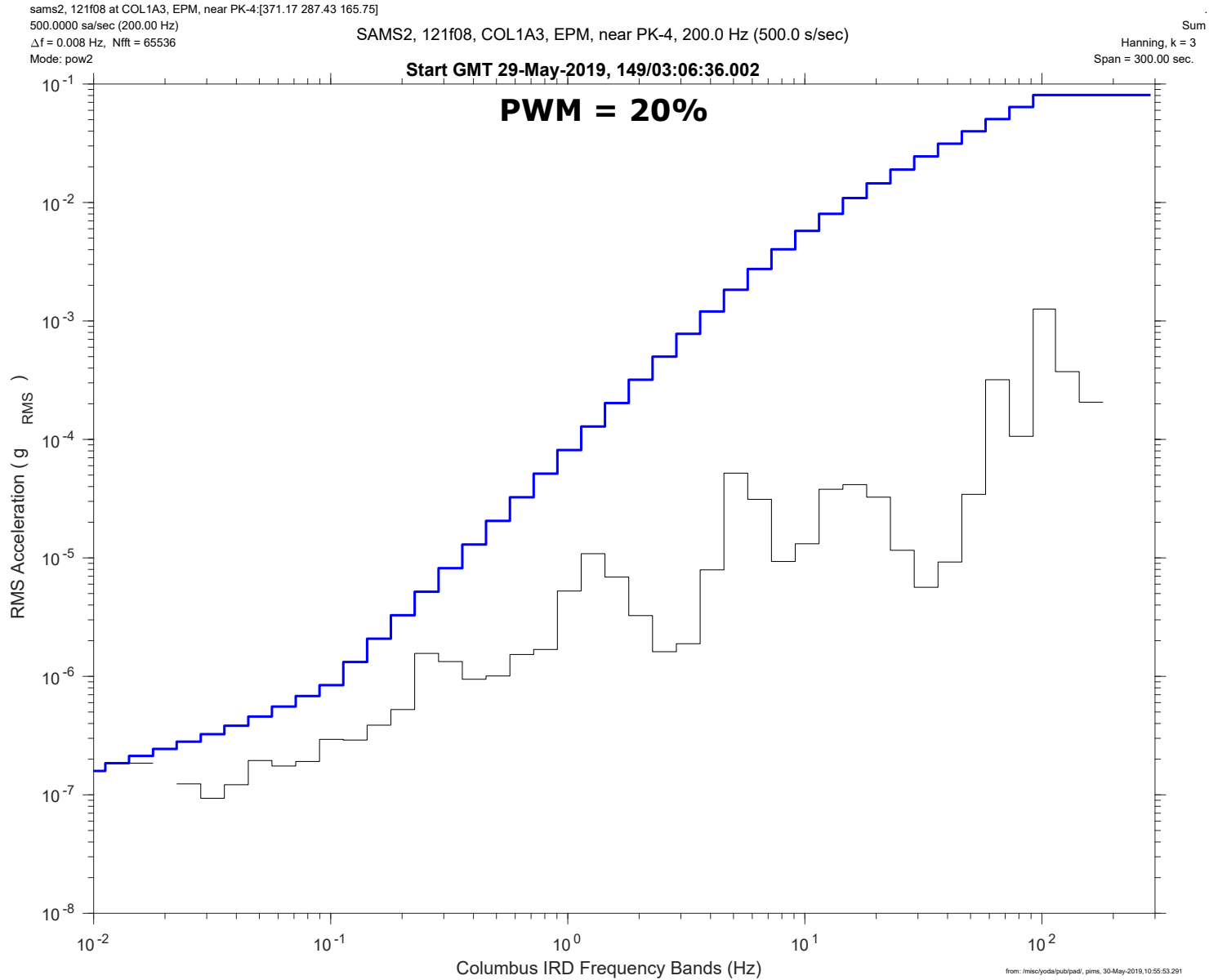


Fig. 15: One-Third Octave RMS Acceleration vs. Frequency (PWM = 20%).

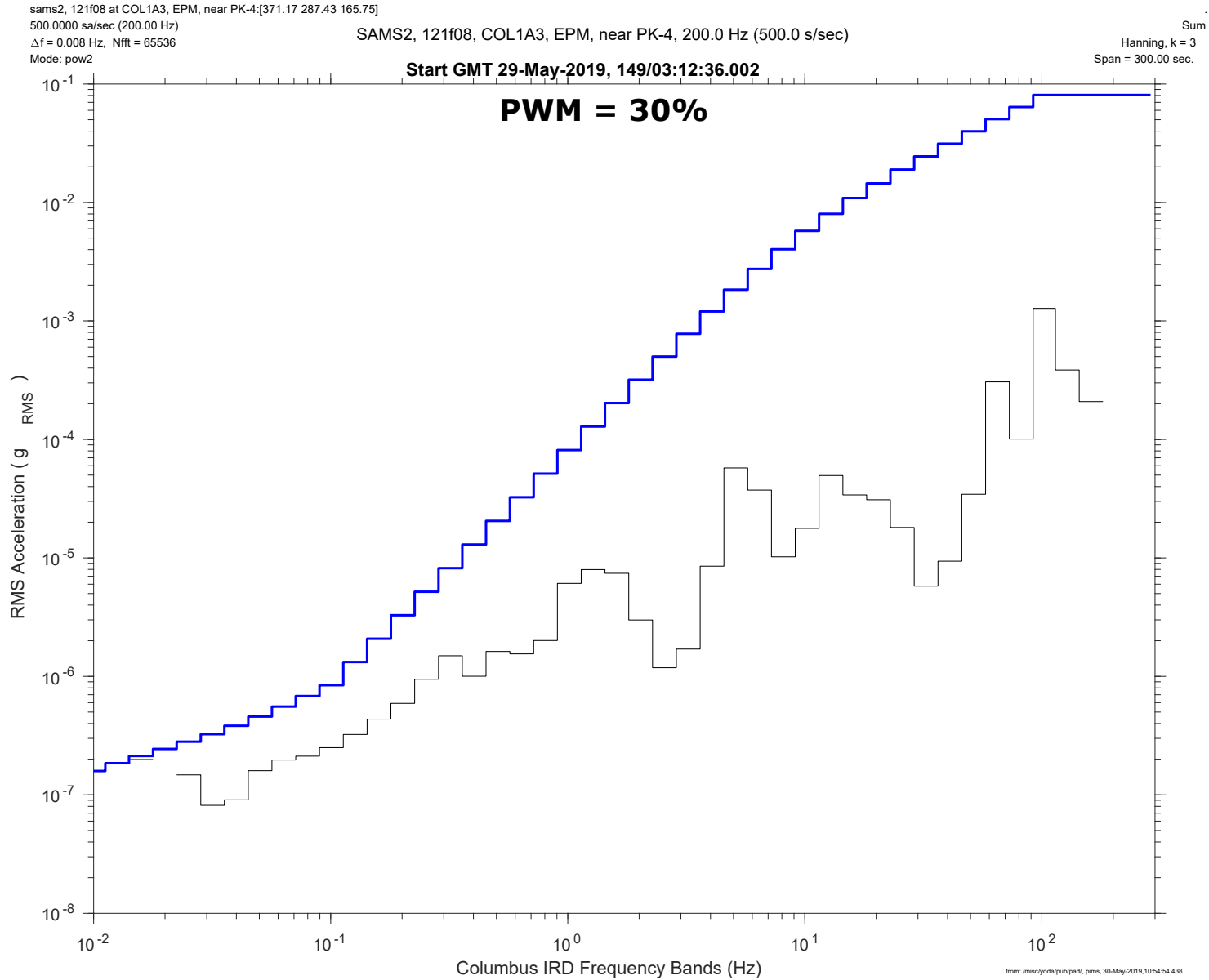


Fig. 16: One-Third Octave RMS Acceleration vs. Frequency (PWM = 30%).

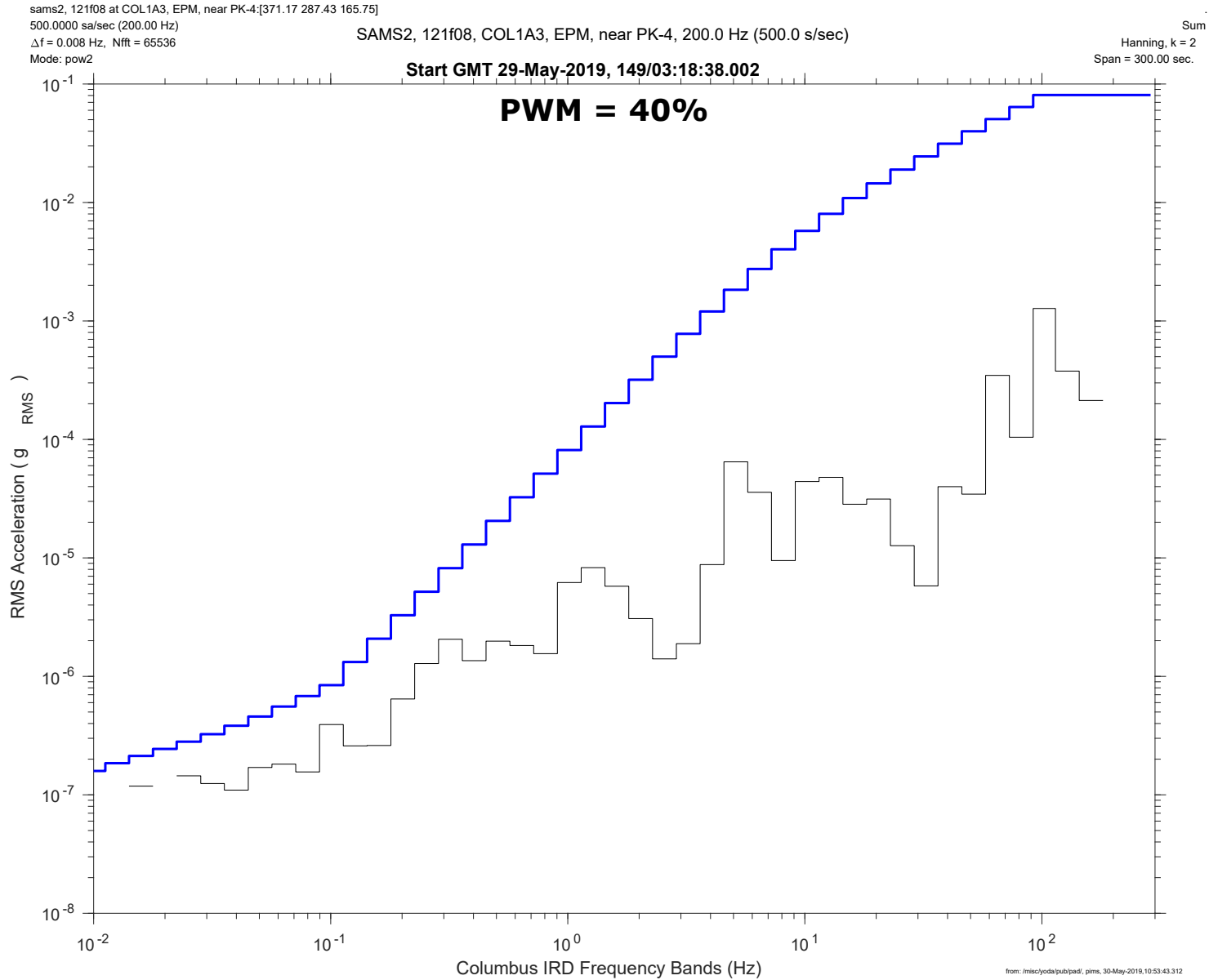


Fig. 17: One-Third Octave RMS Acceleration vs. Frequency (PWM = 40%).

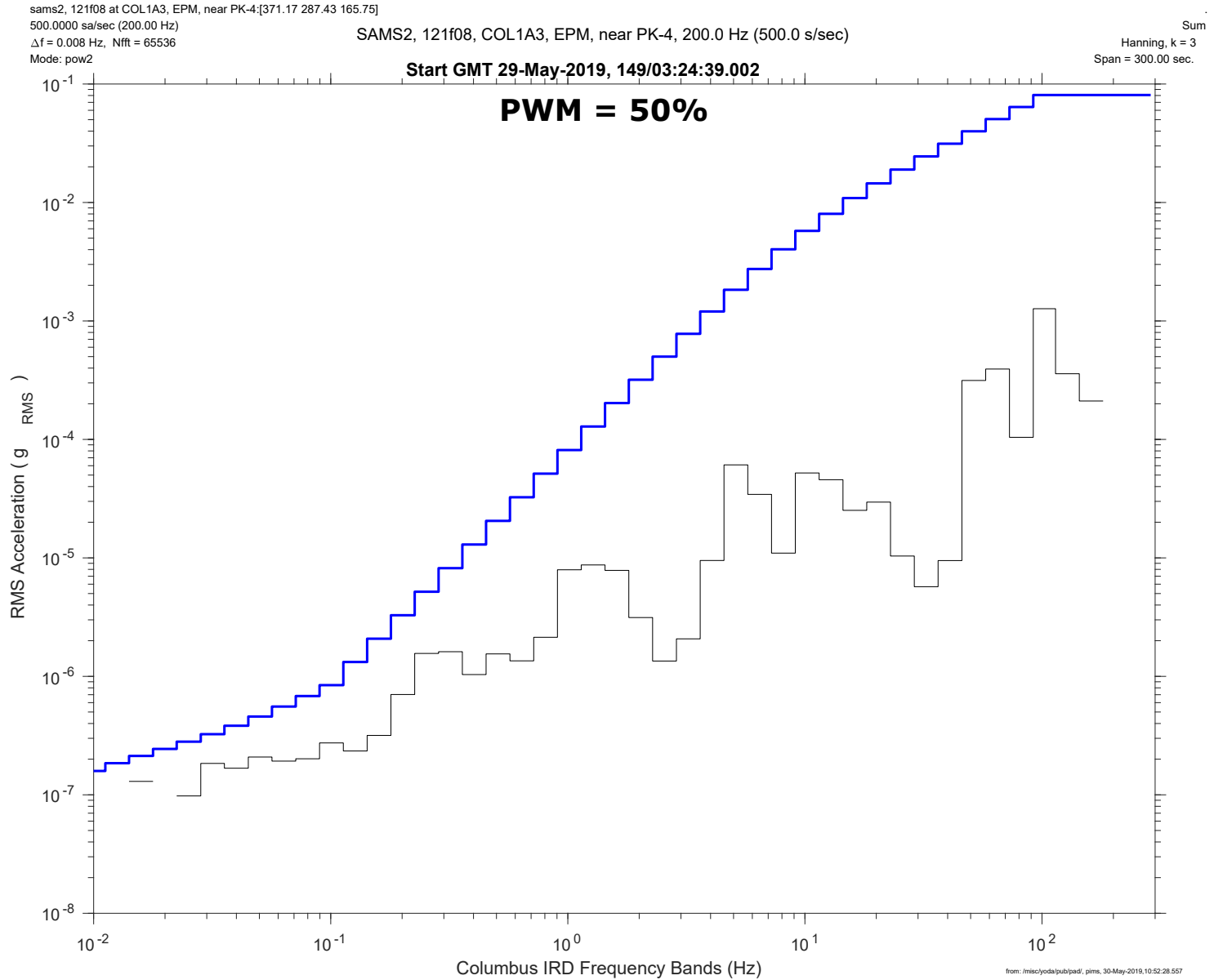


Fig. 18: One-Third Octave RMS Acceleration vs. Frequency (PWM = 50%).

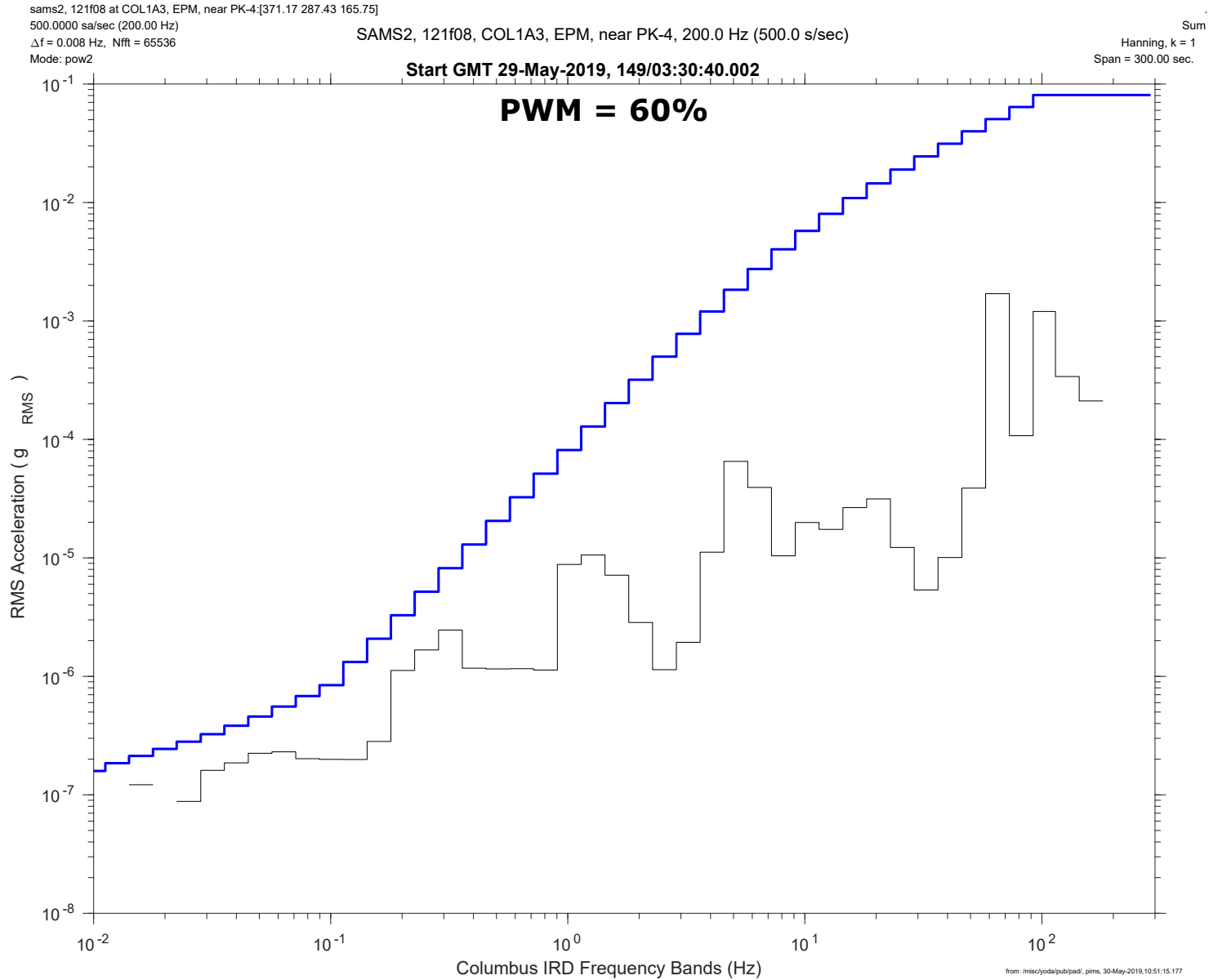


Fig. 19: One-Third Octave RMS Acceleration vs. Frequency (PWM = 60%).

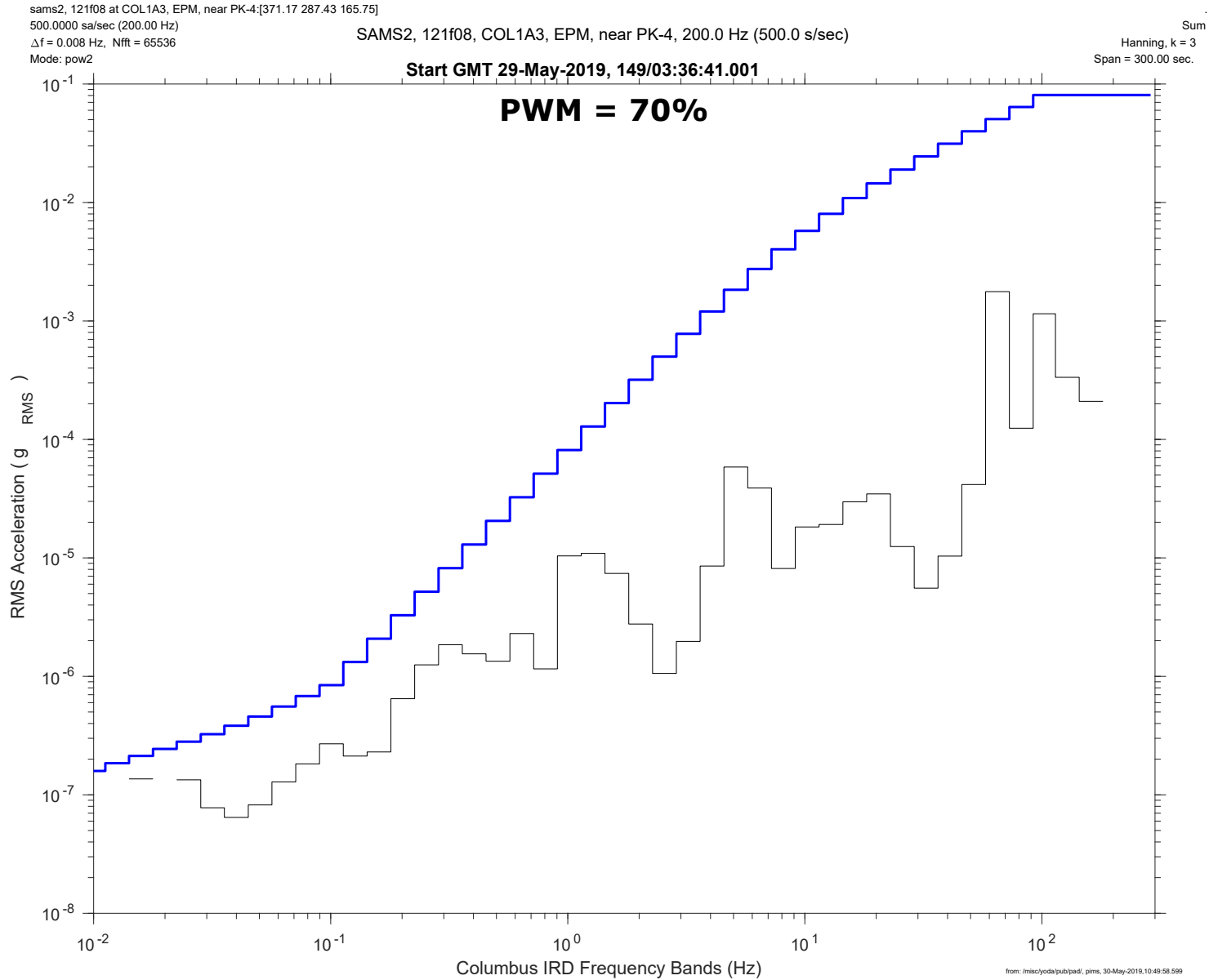


Fig. 20: One-Third Octave RMS Acceleration vs. Frequency (PWM = 70%).

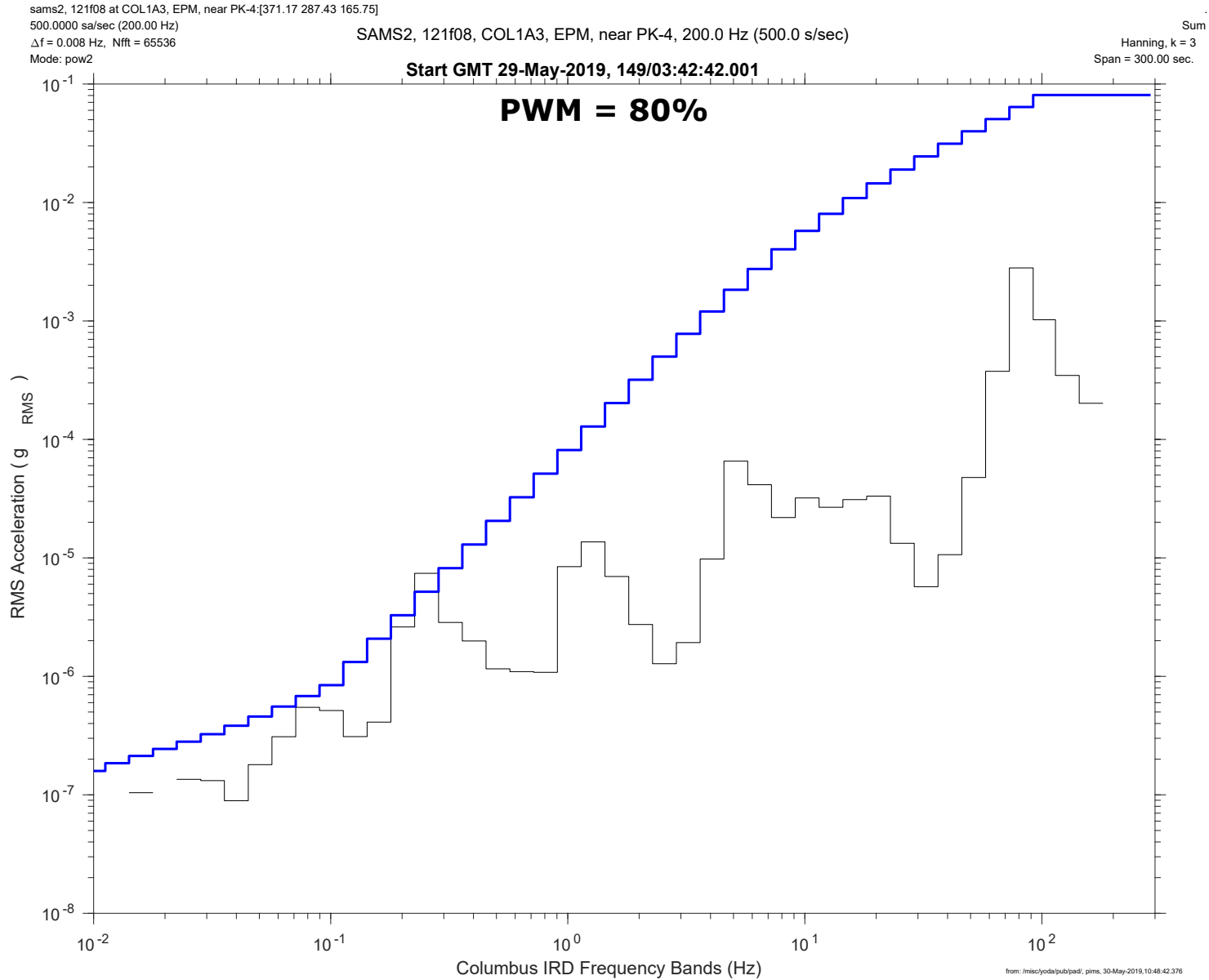


Fig. 21: One-Third Octave RMS Acceleration vs. Frequency (PWM = 80%).

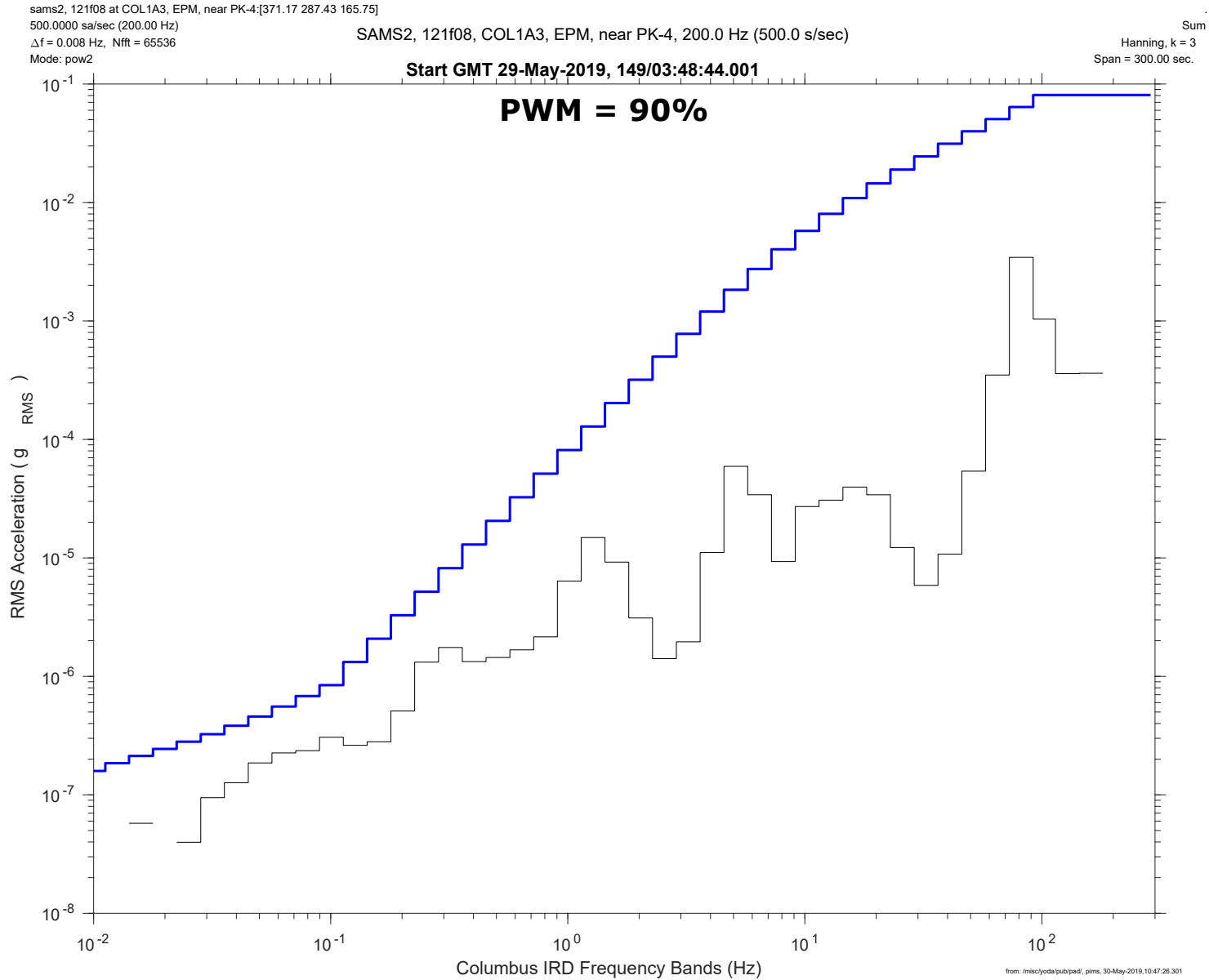


Fig. 22: One-Third Octave RMS Acceleration vs. Frequency (PWM = 90%).

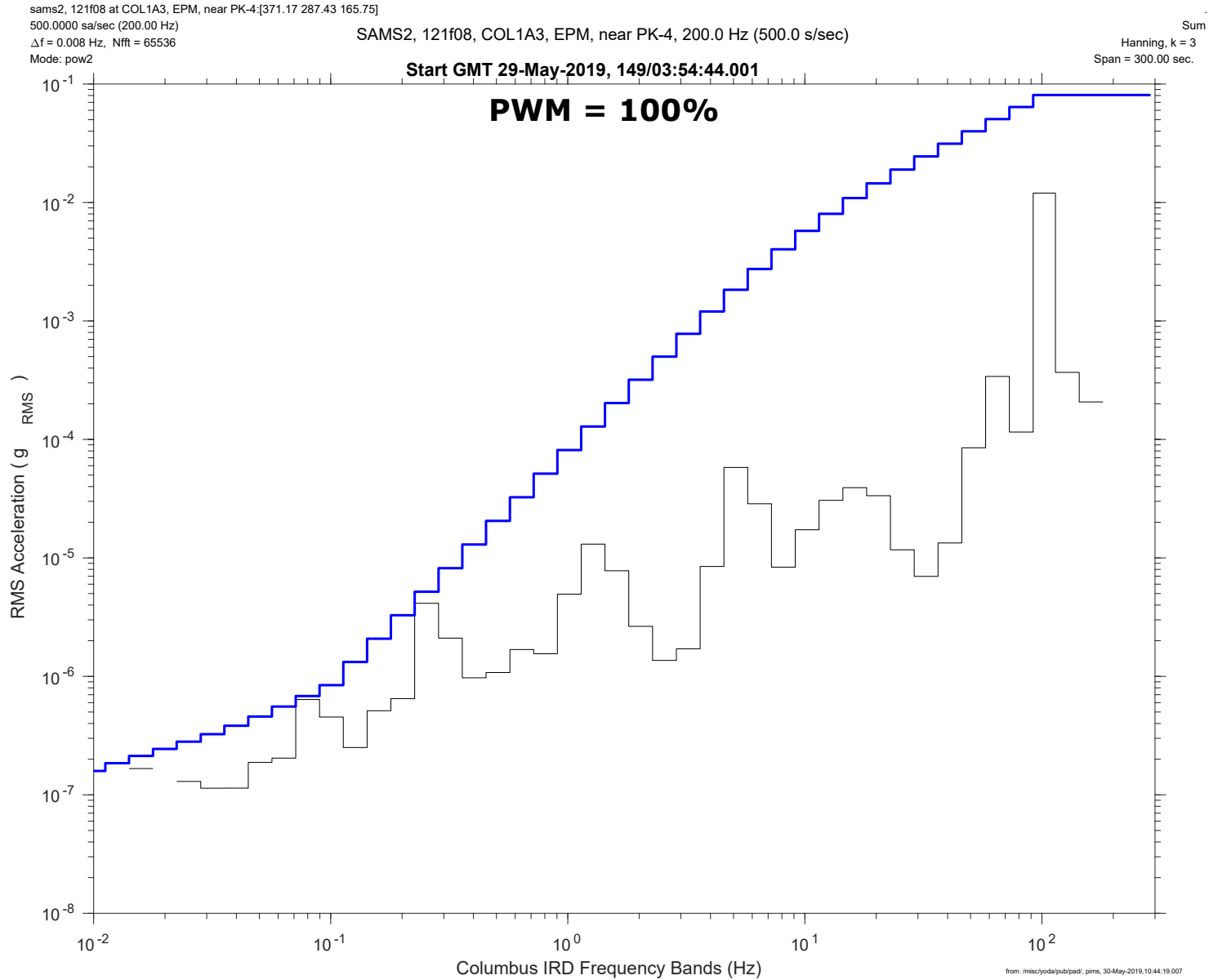


Fig. 23: One-Third Octave RMS Acceleration vs. Frequency (PWM = 100%).