1. INTRODUCTION

The International Space Station (ISS) transmits high-rate telemetry and recorded data via its geosynchronous Tracking and Data Relay Satellites (TDRS) constellation of satellites. The ISS is much closer to the Earth and its orbit is not geosynchronous. As a result, because of their relative speeds and trajectories, a two-gimbal, steerable antenna is required to maintain line-of-sight for optimal signal strength.

When the ISS trajectory takes it beyond the coverage of its currently-being-tracked TDRS satellite, the SGANT Ku-band antenna initiates a handover to quickly recover its continuous high-data-rate communications with its next TDRS satellite. Physically, the antenna's two-axis gimbal mechanism rapidly slews its 6-foot dish to the predicted position of the next TDRS, potentially followed by a brief spiral search pattern to acquire the strongest signal if initial pointing is not optimal for signal strength. This system's smarts rotate the dish in azimuth (XEL) and elevation (EL) in such a way as to gain optimal line-of-sight. Once locked onto the "next" TDRS, the tracking logic switches to closed-loop tracking for precise, ongoing pointing adjustments. Thus, there are 2 modes for moving the Ku-band antenna dish: (1) fast slew (like for handovers) to transition from "this" target satellite to the "next" target satellite, and (2) once we lock-on to the "next" TDRS satellite, we slowly rotate in azimuth and elevation via the 2 gimbals to accurately point the dish. The slew/handover process can last roughly between about 30 seconds to a minute and causes temporary loss of signal. The aim is to minimize downtime in relaying video, telemetry, and experiment data between the ISS and ground stations via the geosynchronous TDRS network.

On GMT 2026-01-21, this system experienced a relatively brief, Ku outage reportedly from approximately GMT 11:19 to 13:37, due to an unexpected under-temperature safing condition for antenna group 1 – ISS likes to keep its feathers numbered, so it has a redundant antenna system. This condition was soon resolved and nominal operations resumed.

This document focuses on a time span around the time of this outage to highlight the vibratory impact of this Ku-band antenna tracking system, which does have impact on the vibratory environment throughout the pressurized modules in the ISS.

A set of annotated spectrogram variants is provided (around the time of the reported Ku outage) to highlight the vibratory impact of this Ku-band antenna tracking system and to separate confounds (notably 2 crew exercise sessions) from Ku-motion-related signatures, and to identify repeatable narrowband features that appear during fast slew/handover or "slow, closed-loop tracking" activity. A narrowband root-mean-square (RMS) acceleration overlay derived from computed power spectral density values (a la Parseval) is included as a intuitive metric to support correlation with Ku antenna/gimbal telemetry and operational timelines.

Fig. 1: The ISS SGANT Ku-band tracking antenna system.

2. QUALIFY

This section provides a qualitative, figure-by-figure interpretation of the Ku handover / spiral search vibratory signatures as observed in SAMS sensor 121f03 at US LAB, LAB1O1. The intent is to (1) separate potentially confounding sources (e.g., crew exercise) from Ku-related signatures, (2) identify repeatable spectral features that align with fast slew/handover events, and (3) highlight where external telemetry is required to move from “plausible association” to “confirmed causality.”

Walkthrough by figure in order shown at the end of this document:

Figure 2: `Original Spectrogram`
An 8-hour, 20 Hz color spectrogram computed from SAMS data for sensor 121f03 mounted in the US LAB on LAB1O1. This figure is intentionally unannotated and serves as the “pristine” baseline. The following annotated copies selectively call out distinct signatures and potential confounds visible in this same underlying spectrogram: (i) two crew exercise periods, (ii) two gimbal signatures (one continuous, one with a pause), (iii) four narrow spectral components associated with fast handover slews, (iv) a zoom-in to make short-duration handover features easier to see, (v) a narrowband RMS overlay trace centered near 5.2 Hz derived from the PSD (Parseval), and (vi) a short “chandelier” feature that warrants dedicated scrutiny.

Figure 3: `Two Crew Exercise Sessions`
Two crew exercise periods are annotated. These periods introduce broad, low-frequency structure-borne vibration that can overlap or partially mask Ku-related content near the ~5 Hz region. For Ku attribution, these time spans should be treated as potential confounds unless independent timing corroboration shows Ku slews/handover occurring outside (or distinctly within) exercise windows.

Figure 4: `The "Ramp" Gimbal`
One of the two gimbal signatures (informally the “ramp” gimbal) continues slewing throughout the full span with no obvious pause. The dominant feature appears as a smooth, monotonic frequency ramping track, consistent with a continuous slew profile. This provides a useful qualitative discriminator: Ku-related events that depend on one gimbal pausing should not be mapped to this one, it does NOT pause in the time span analyzed.

Figure 5: `The "Swoosh" Gimbal`
The second gimbal signature (informally the “swoosh” gimbal) exhibits a pronounced pause interval (roughly GMT 11:30 to 13:30, as annotated). Unlike the linear “ramp” track, this signature is non-linear in time-frequency space and shows a somewhat repeated pattern between about 10 and 18 Hz. The presence of a pause interval is a key discriminator for aligning Ku outage reports with mechanical motion states. Albeit with a distinctive "swoosh" pattern, this gimbal produces a somewhat nebulous [turbulent] vibratory signature.

Figure 6: `Four "Handover" Spectral Peaks`
Four narrow spectral components are annotated in red at approximately 5.2, 7.8, 10.5, and 13.1 Hz and appear to intensify during fast slew/handover activity. From vibration data alone, it is not possible to uniquely assign each component to a specific gimbal or mechanical degree-of-freedom; that attribution requires time-aligned gimbal/Ku antenna telemetry (rates/positions) and operational logs.

Figure 7: `Zoom-In on Some "Handover" Spectral Peaks`
A zoom-in view is used to make short-duration handover slew events easier to detect visually. These events can be difficult to identify in long-span spectrograms because they are brief and narrowband.

Figure 8: `Parseval Root-Mean-Square Acceleration Overlay`
A black overlay trace shows the relative (normalized) RMS acceleration in a narrowband from 5.05 to 5.35 Hz (centered near 5.2 Hz), computed by integrating the PSD over frequency and taking the square root (Parseval). Spikes in this trace align with periods where the 5.2 Hz component strengthens, providing a compact scalar metric for “handover intensity” at this band.

Figure 9: `Interesting "Chandelier" Spectral Feature`
A short-duration, visually distinctive “chandelier” feature is highlighted (approximately 4.11–6.6 Hz over several minutes from GMT 14:55:16 to 15:03:54; annotated in the figure). While it appears Ku-motion-related, the vibration data alone cannot establish source. This is an excellent candidate for future work/correlation against Ku antenna motion state, gimbal rates, and any reported Ku-motion dynamics-related questions.

3. QUANTIFY

The qualitative patterns above motivate a quantitative metric that can be trended and compared across time windows. For the Ku handover / fast-slew signatures, a practical starting point is a narrowband RMS derived from the spectrogram's, time-sliced PSDs.

Narrowband RMS from the PSD (Parseval)

Let $\mathrm{PSD}(f,t)$ be the one-sided acceleration power spectral density associated with each spectrogram time bin. A narrowband RMS acceleration for a frequency interval $[f_1, f_2]$ is computed as:

$$a_{\mathrm{RMS}}(t) = \sqrt{\int_{f_1}^{f_2} \mathrm{PSD}(f,t)\, df}.$$

For Figure 8, the chosen band is $[f_1, f_2] = [5.05, 5.35]$ Hz, centered near the ∼5.2 Hz component that strengthens during fast slew/handover activity. The overlay is intentionally shown as a relative (normalized) trace to emphasize timing/alignment of peaks with candidate handover events rather than absolute amplitude calibration. For best quantification, see the source of the black trace information in Figure 10.

4. CONCLUSION

Across the 8-hour analysis span on GMT 2026-01-21, the 121f03 spectrograms show multiple distinct signatures consistent with Ku antenna slow/tracking motion and handover/fast-slew activity. Two gimbal-related signatures are apparent: a continuously slewing track ("ramp" gimbal) and a non-linear "swoosh" signature with a clear pause interval. Four narrow spectral components near 5.2, 7.8, 10.5, and 13.1 Hz strengthen during candidate fast handover slews, and a narrowband RMS trace centered near 5.2 Hz provides a scalar indicator that spikes during these periods.

Exercise periods can overlap parts of the same low-frequency regime and should be treated as confounds unless independently time-aligned to Ku events. Final attribution of individual spectral components to a specific gimbal or Ku motion mode requires correlation with Ku antenna/gimbal telemetry and operational logs; the annotated figures in this document are structured to support that closure activity.

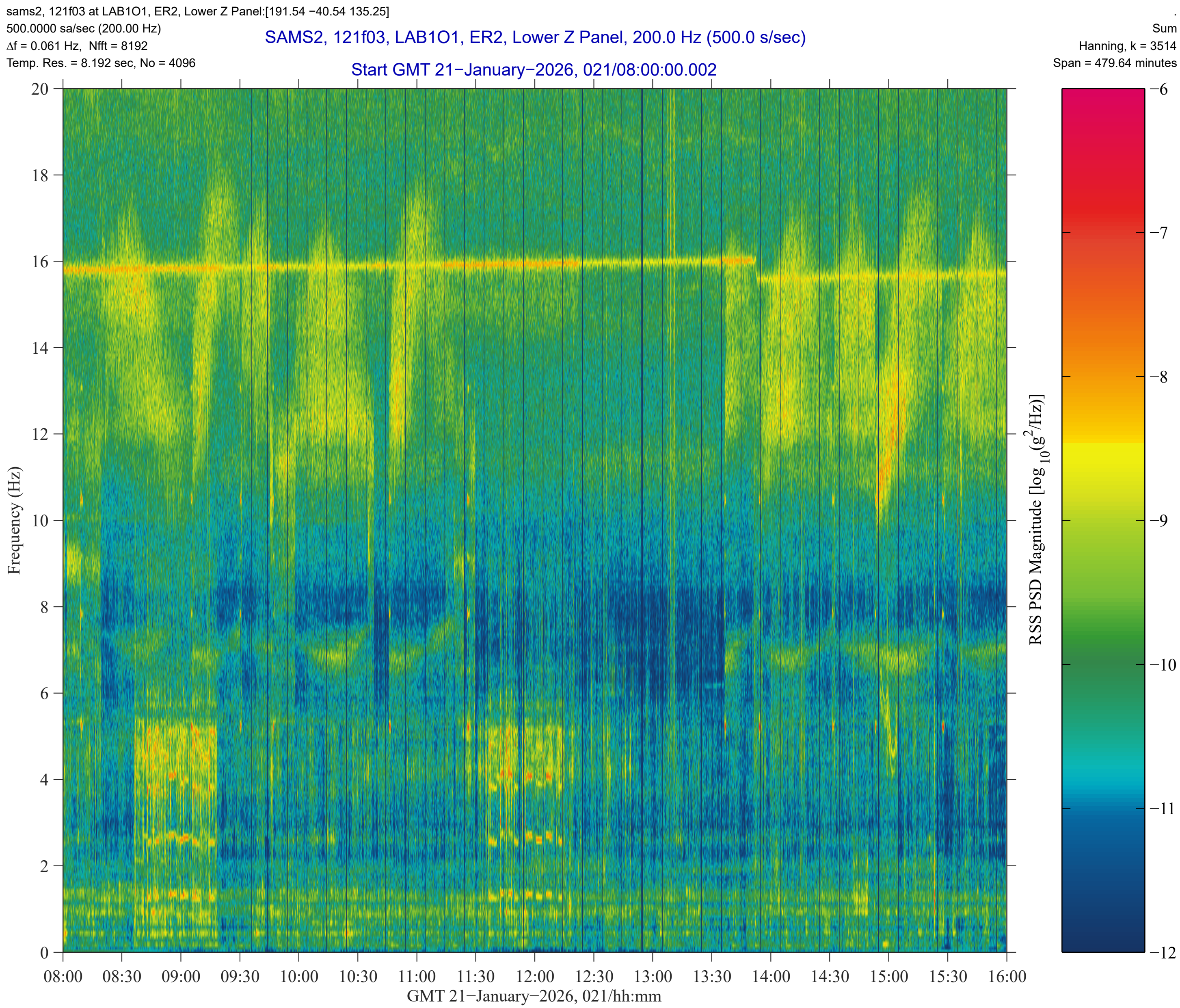

Fig. 2: 8-Hour, 20 Hz SAMS Spectrogram Spanning Reported Ku Outage.

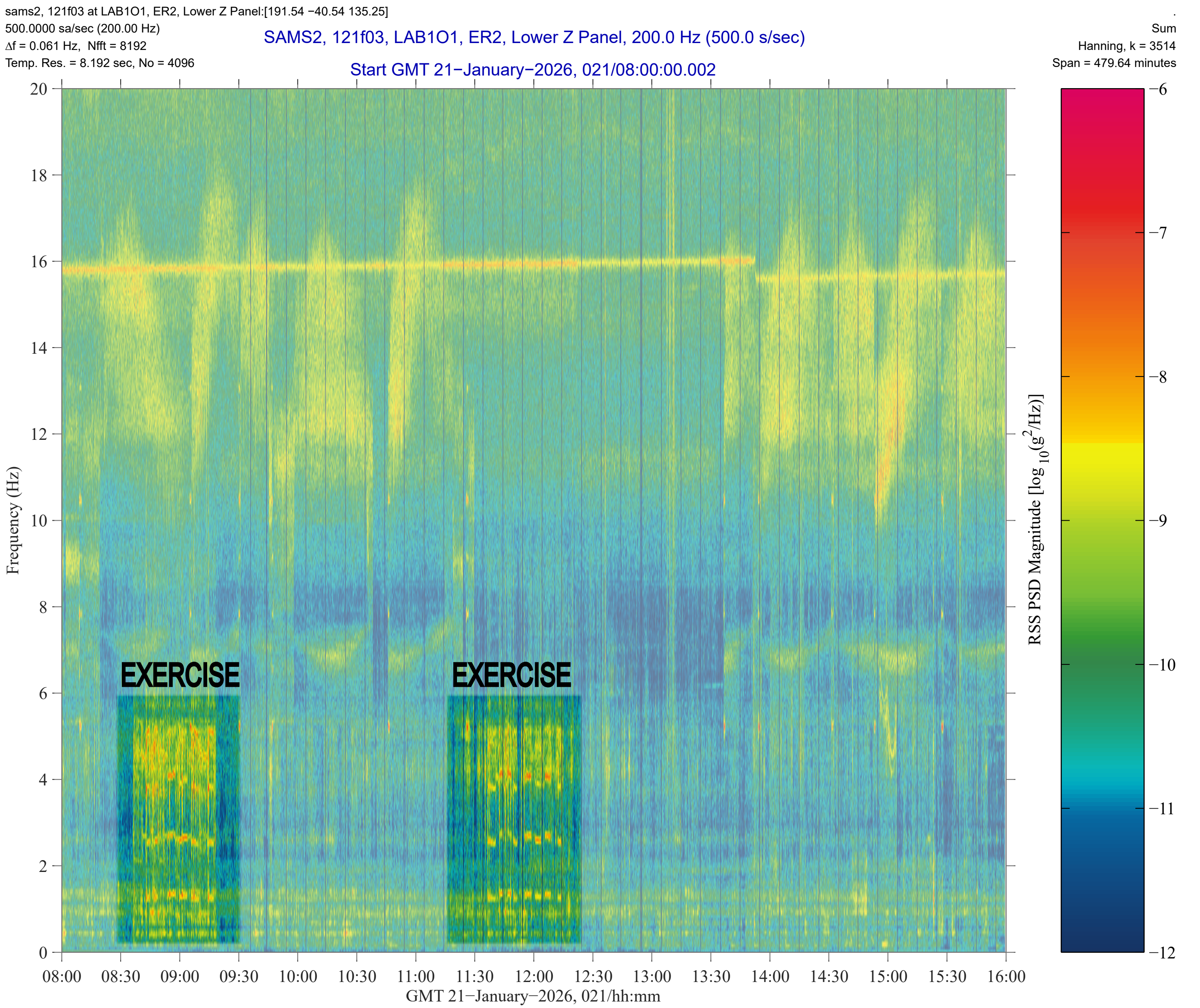

Fig. 3: Two Crew Exercise Periods.

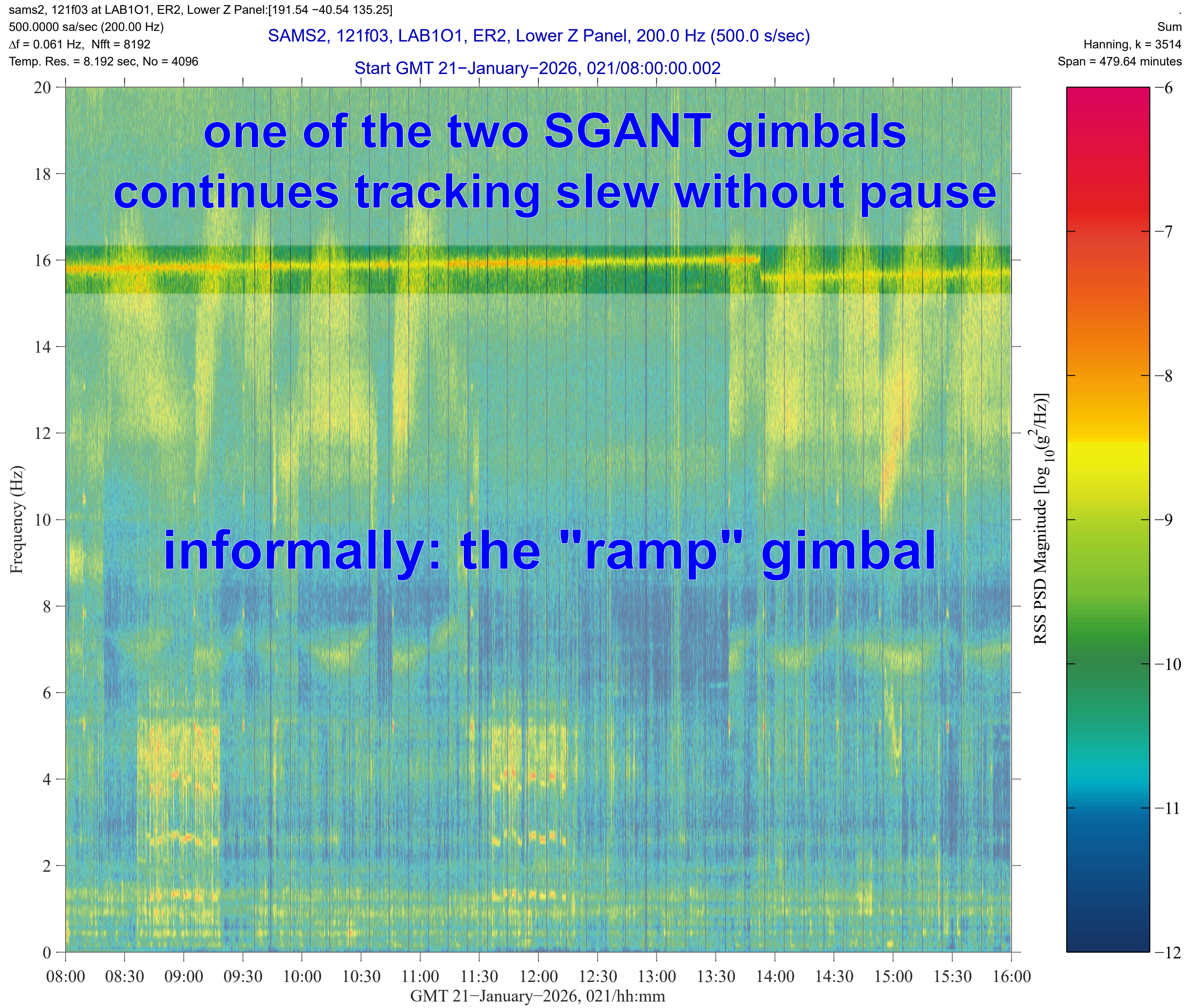

Fig. 4: The "Ramp" Gimbal Signature.

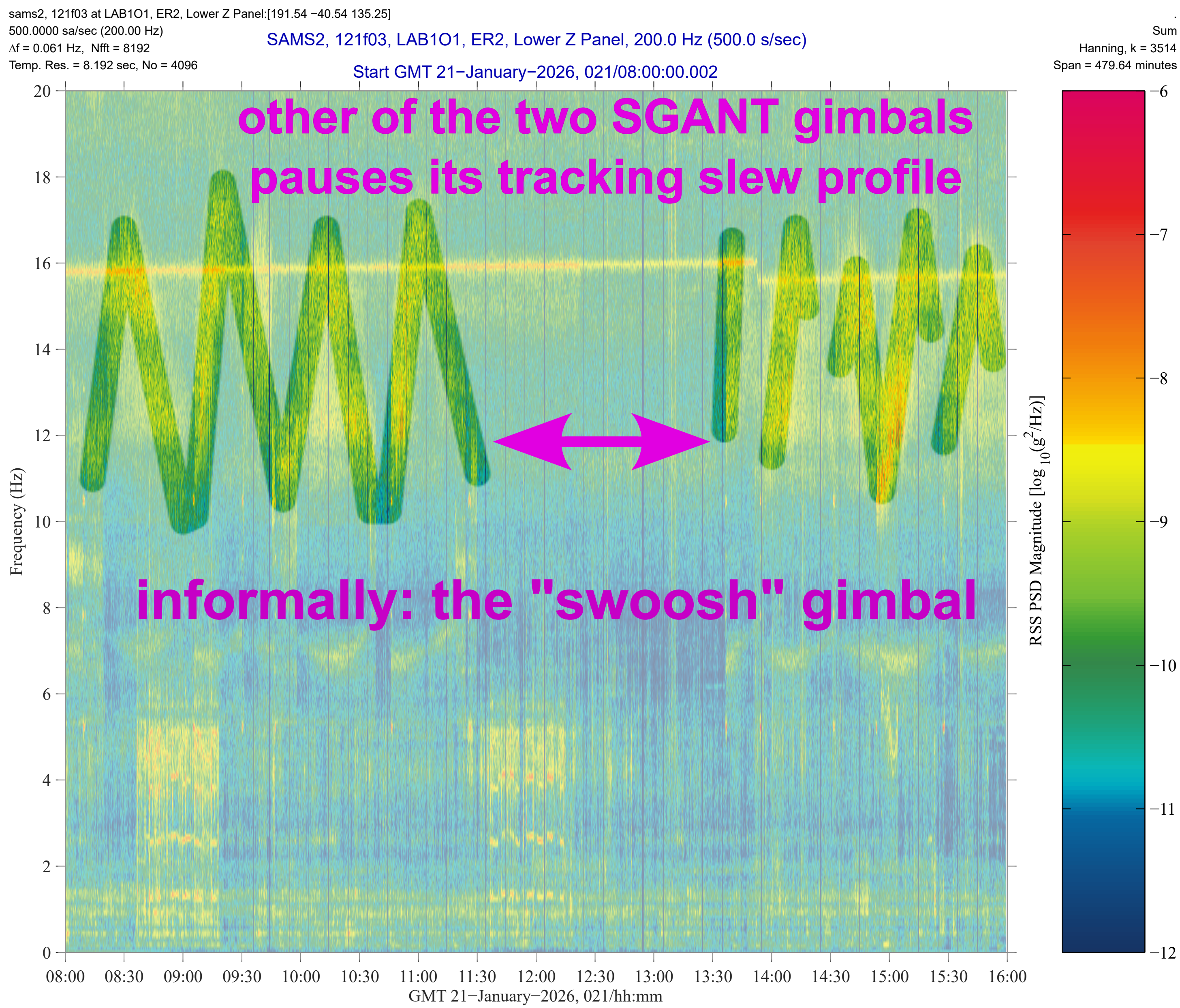

Fig. 5: The "Swoosh" Gimbal Signature.

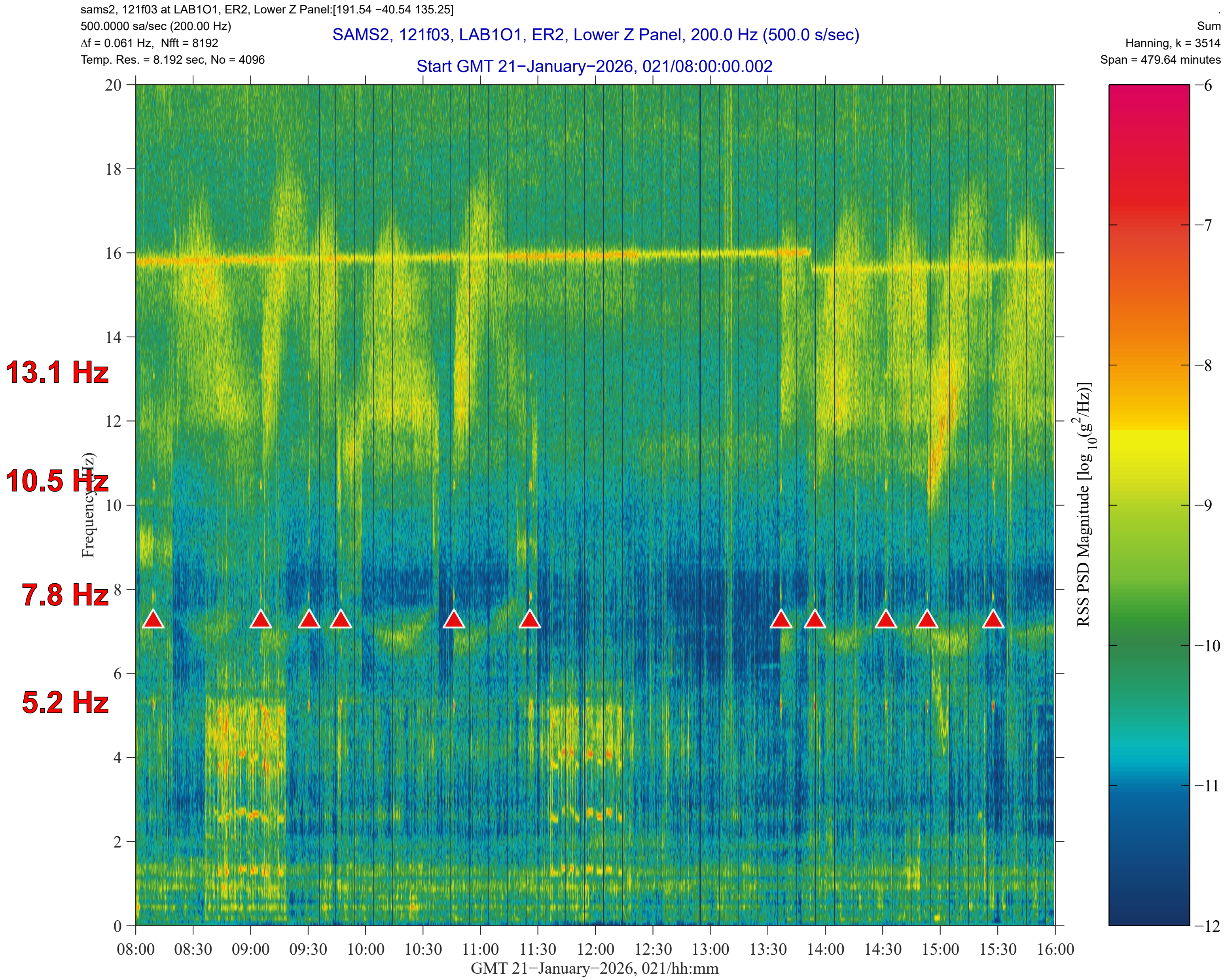

Fig. 6: Four Fast Slew/Handover Narrowband Spectral Signatures.

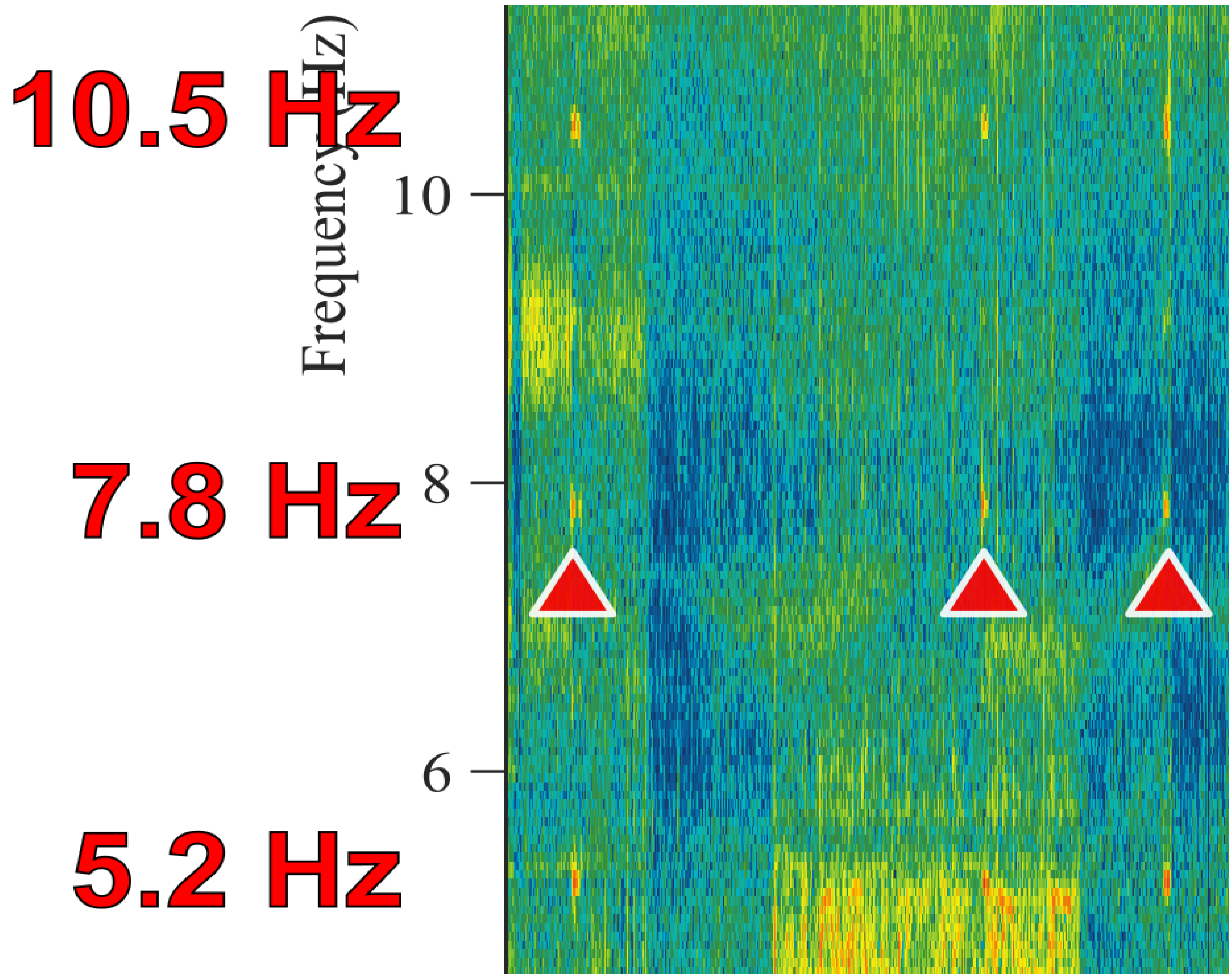

Fig. 7: Zoom-In 3 of 4 Fast Slew/Handover Narrowband Spectral Signatures.

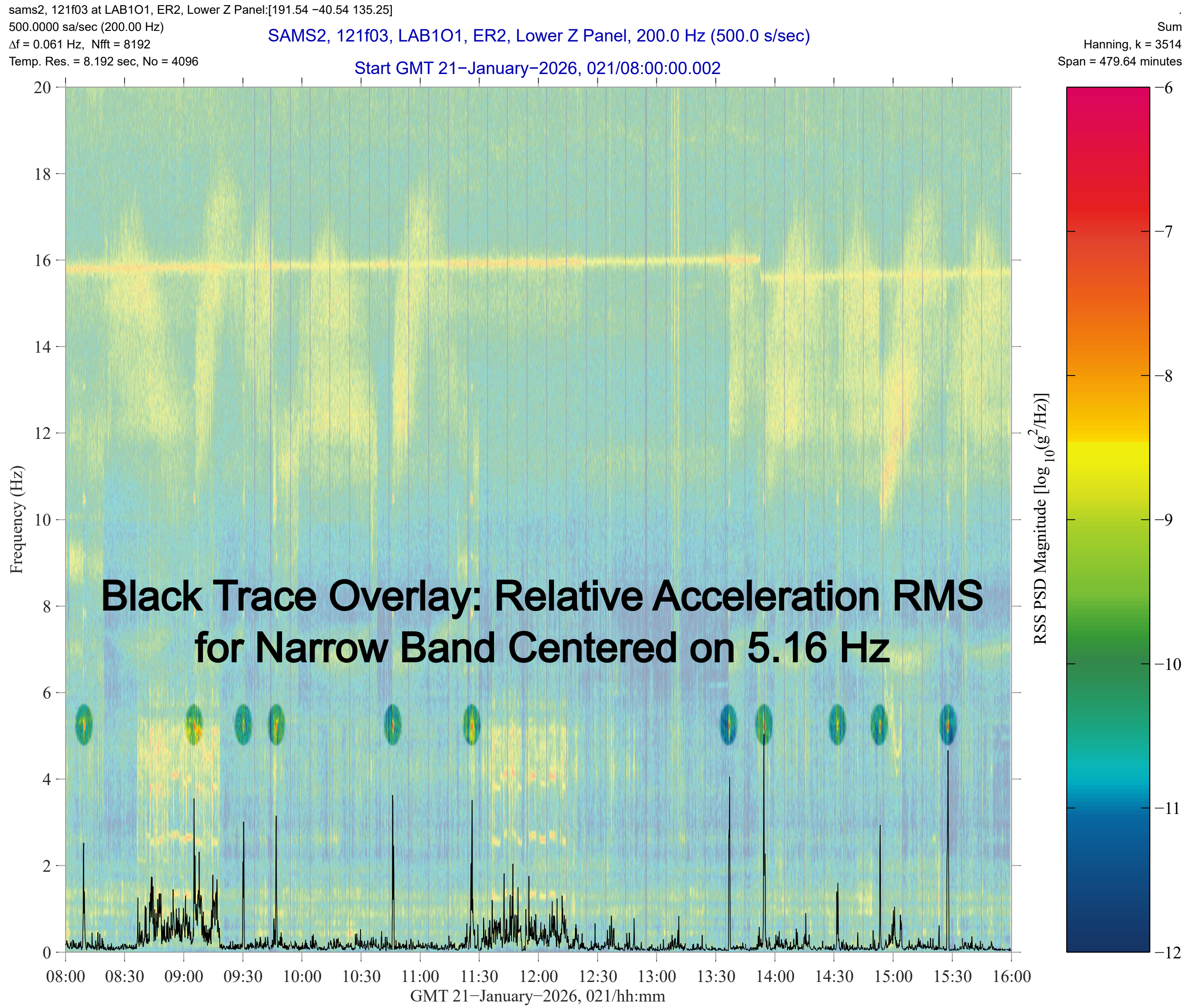

Fig. 8: 8-Second Interval Root-Mean-Square Acceleration Overlay.

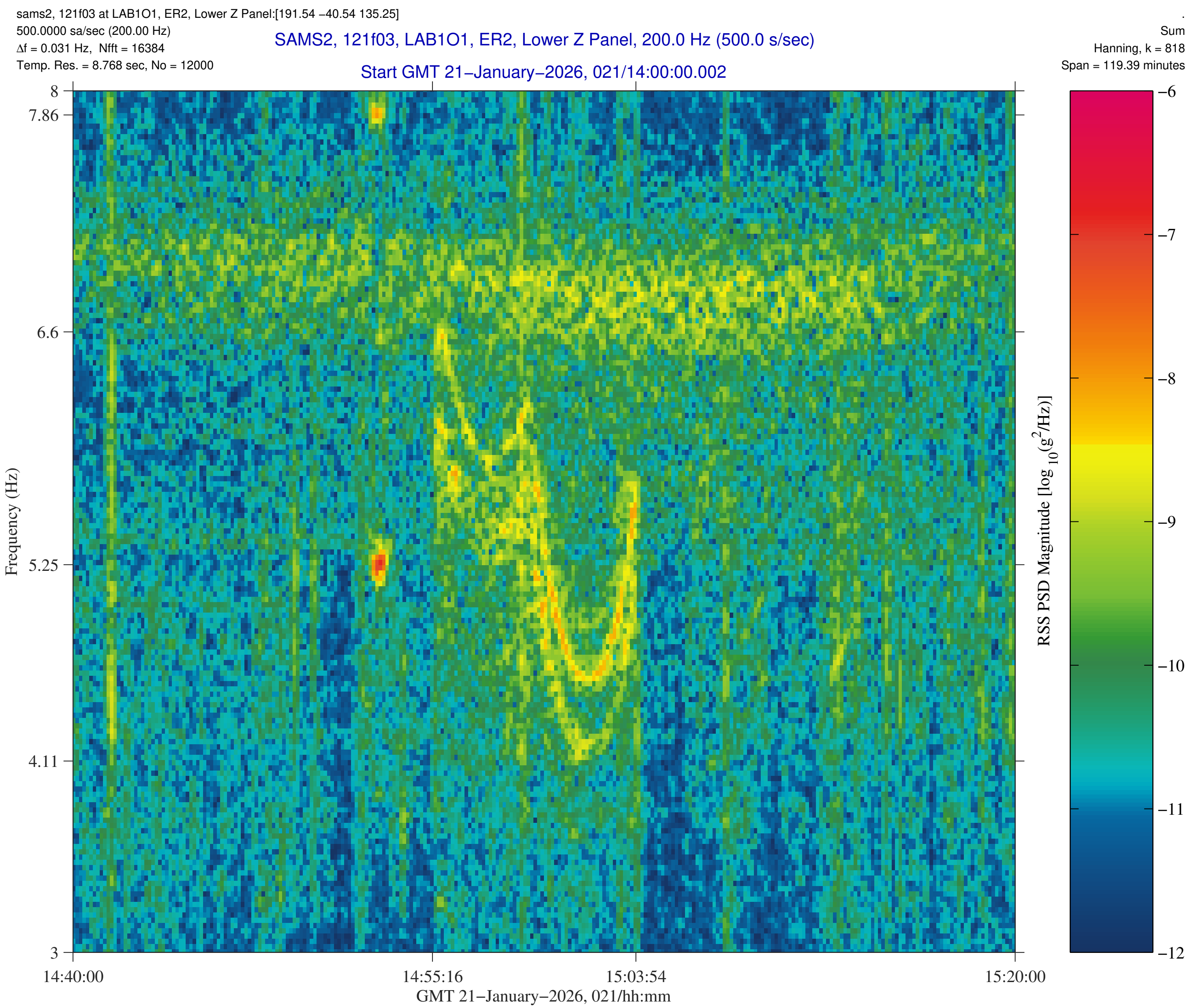

Fig. 9: Spectrogram Zoom-In Shows Interesting "Chandelier" Signature.

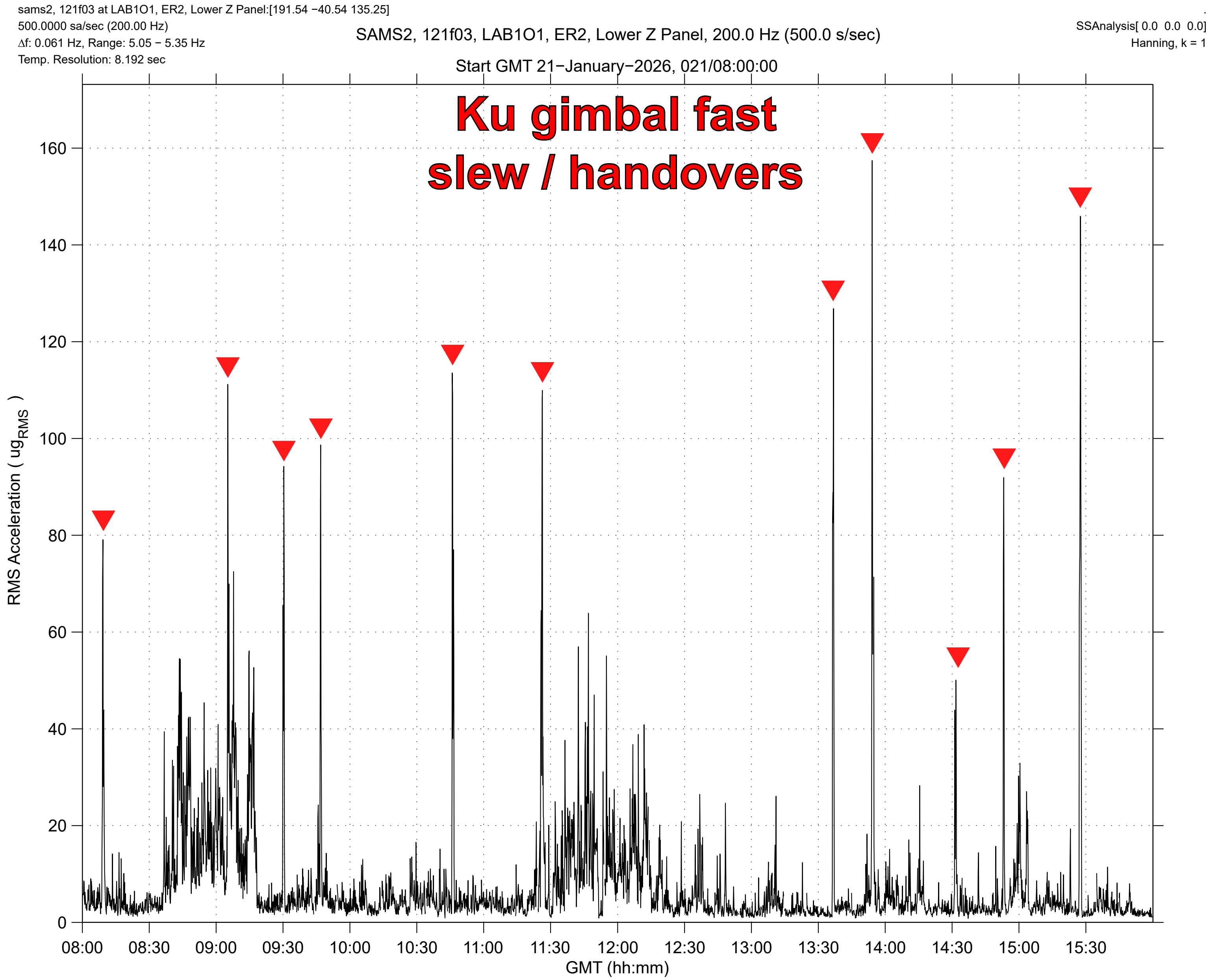

Fig. 10: 8-Second Interval Root-Mean-Square Acceleration Shows Large, Brief Spikes at Ku Handover Times.