Initial Testing of a C-141 Pitch Trim Actuator (PTA) Using Electrical Signature Analysis (ESA)

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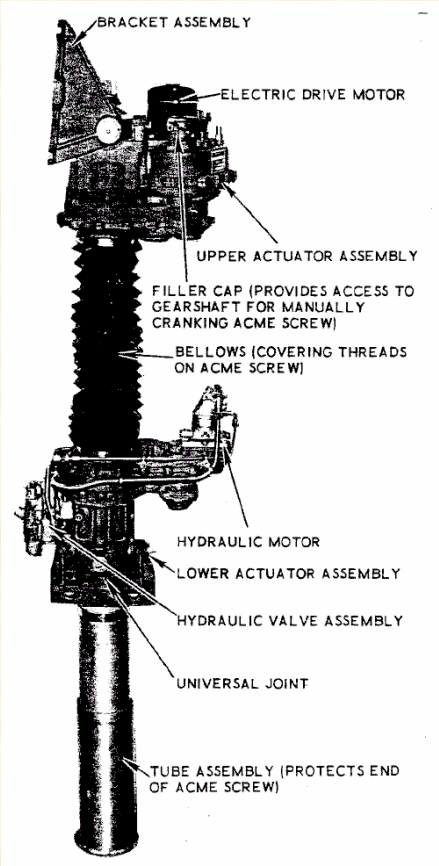
On February 4, 2003, a Preliminary Test Was Performed on a C-141 Pitch Trim Actuator (PTA) at Warner Robins Air Logistics Center (WR-ALC)



Horizontal Stabilizer Actuator Assembly (from T.O. 9H2-4-153-3)

- **Participants included WR-ALC personnel and ORNL (D. F. Cox, J. G. Hansen, H. D. Haynes, and D. E. Welch).**
- **The PTA is also referred to as a horizontal stabilizer actuator.**
- **PTA Motor current signals were recorded in the C-141 cockpit using clamp-on current probes and a digital audio tape recorder. Current levels were monitored in real time using the C-141 Fuel Pump Condition Monitor (FPCM) developed by ORNL.**
- **The PTA was operated through two complete cycles from 4° "nose down" to 10° "nose up".**
- **Recorded signals were analyzed in Oak Ridge.**

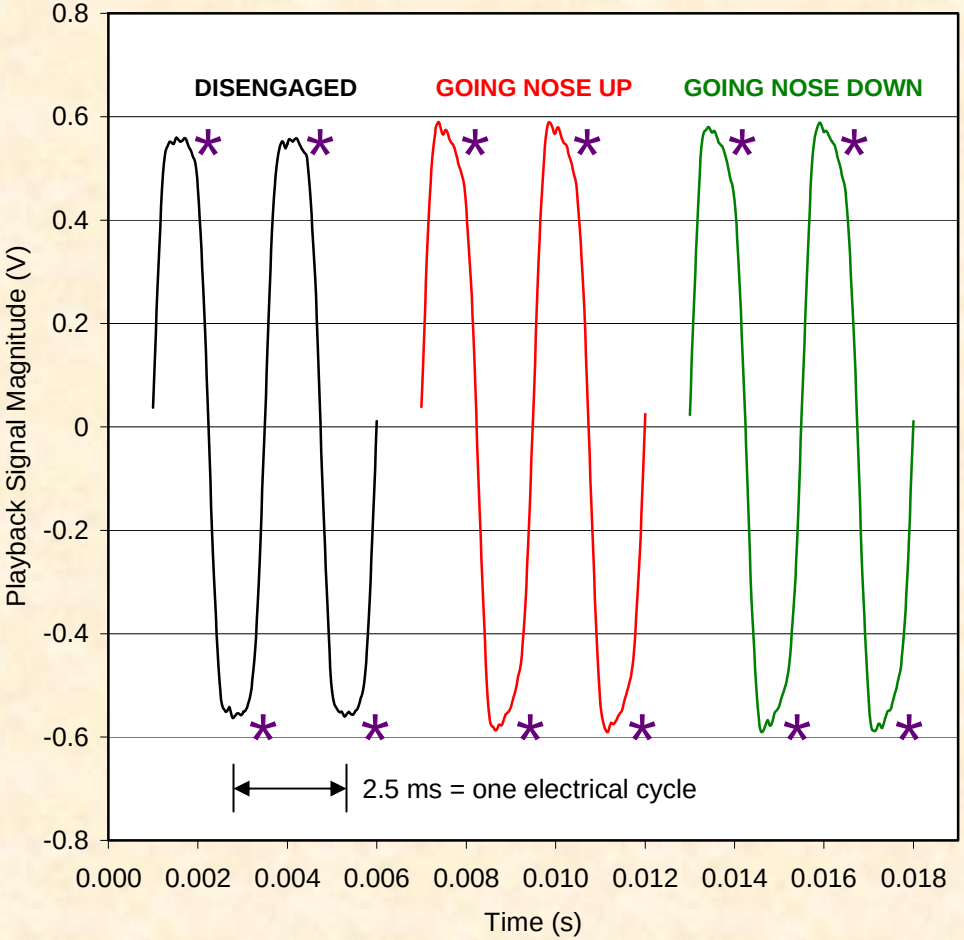
Changes Are Seen in the Motor Current Waveform When The PTA Is Engaged

- ***With the PTA engaged, the pitch of the horizontal tail can be changed in two directions: "nose up" and "nose down".***
- ***Changes are seen in the peaks of the motor current waveforms.****

Close-up of C-141 T-Tail

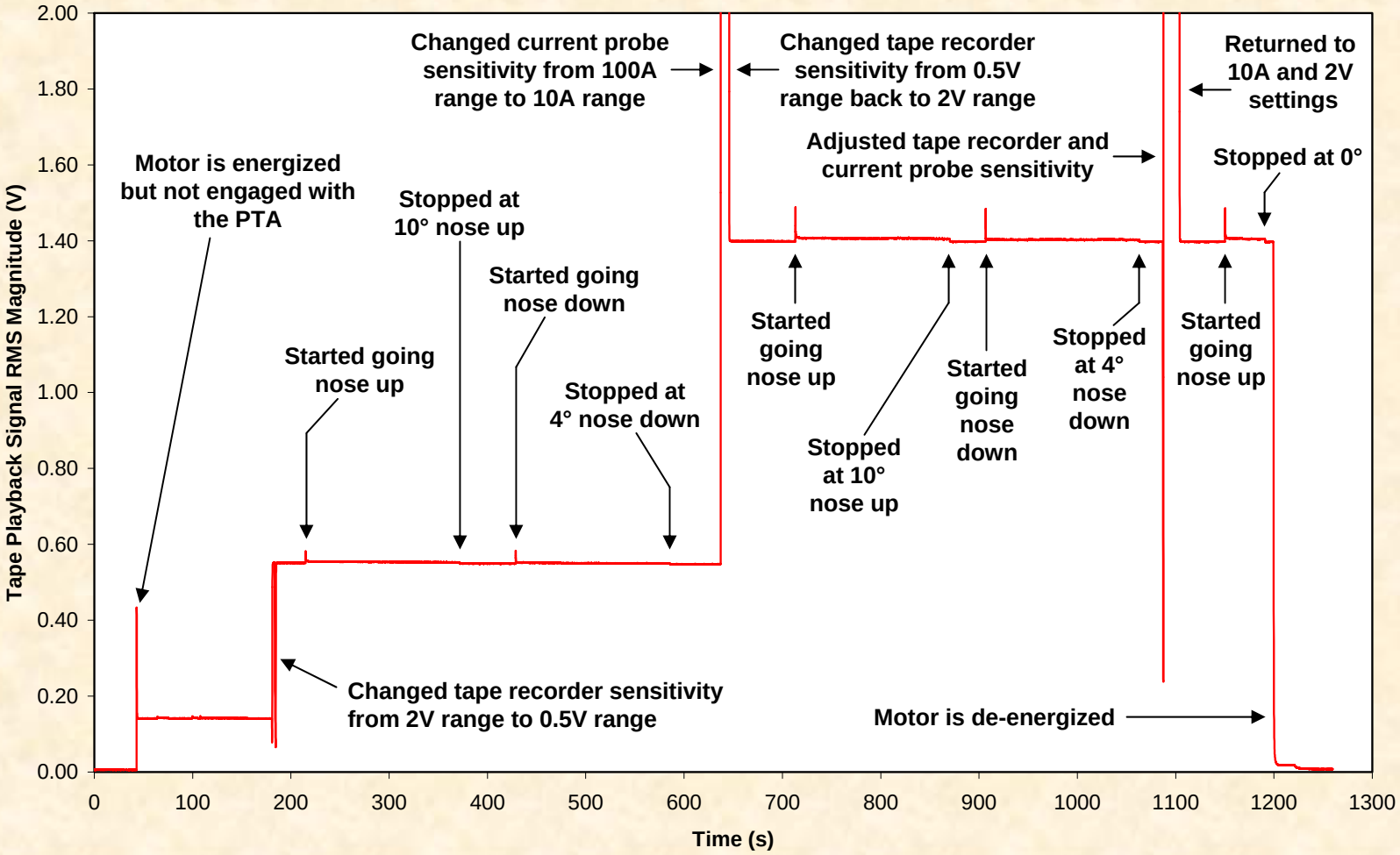
Comparison of PTA Motor Current Waveforms

Two electrical cycles (400 Hz) shown for each operation



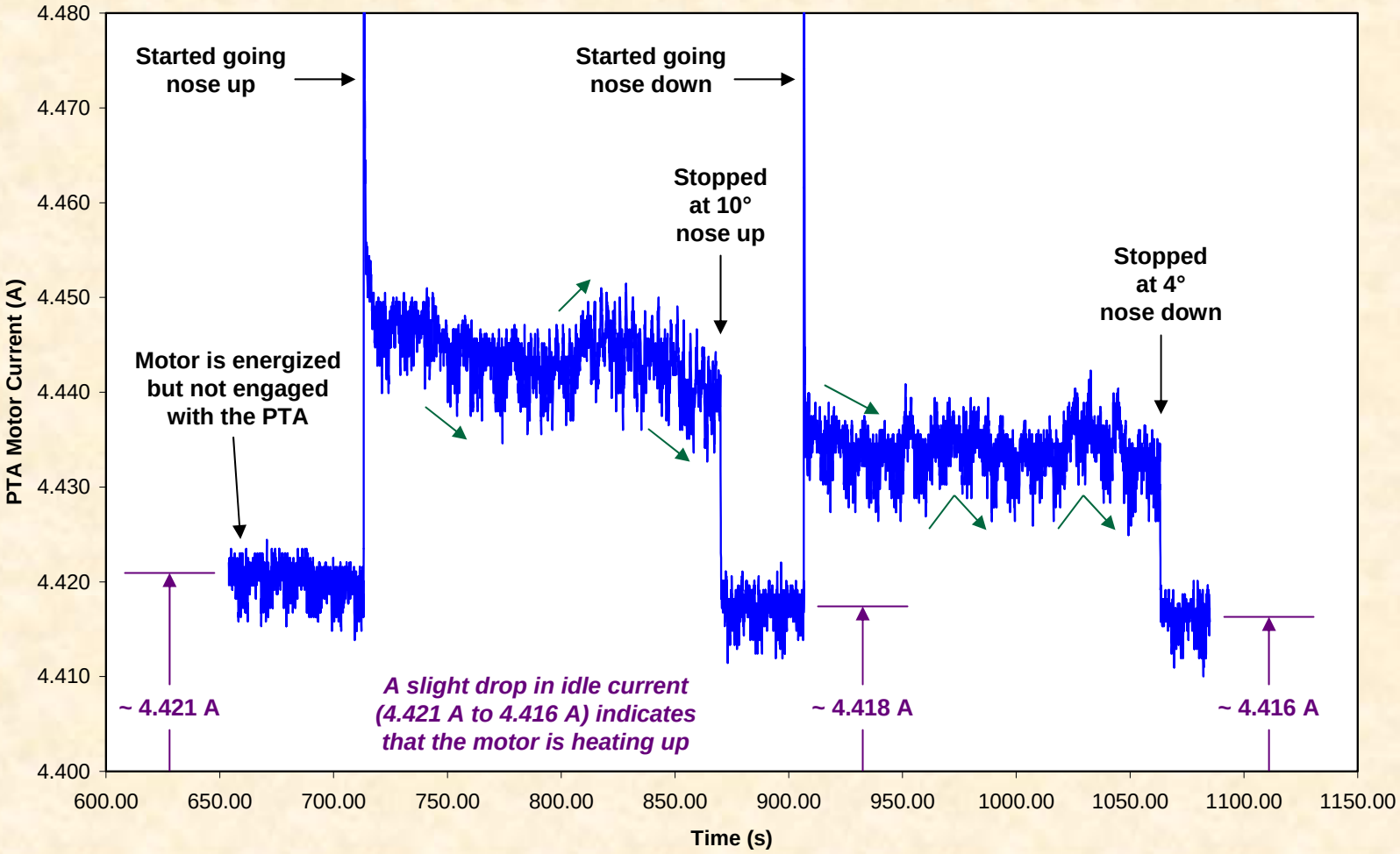
The Recorded Signal Levels Changed Throughout the Test

RMS levels varied as a result of PTA operations and changes in instrumentation settings



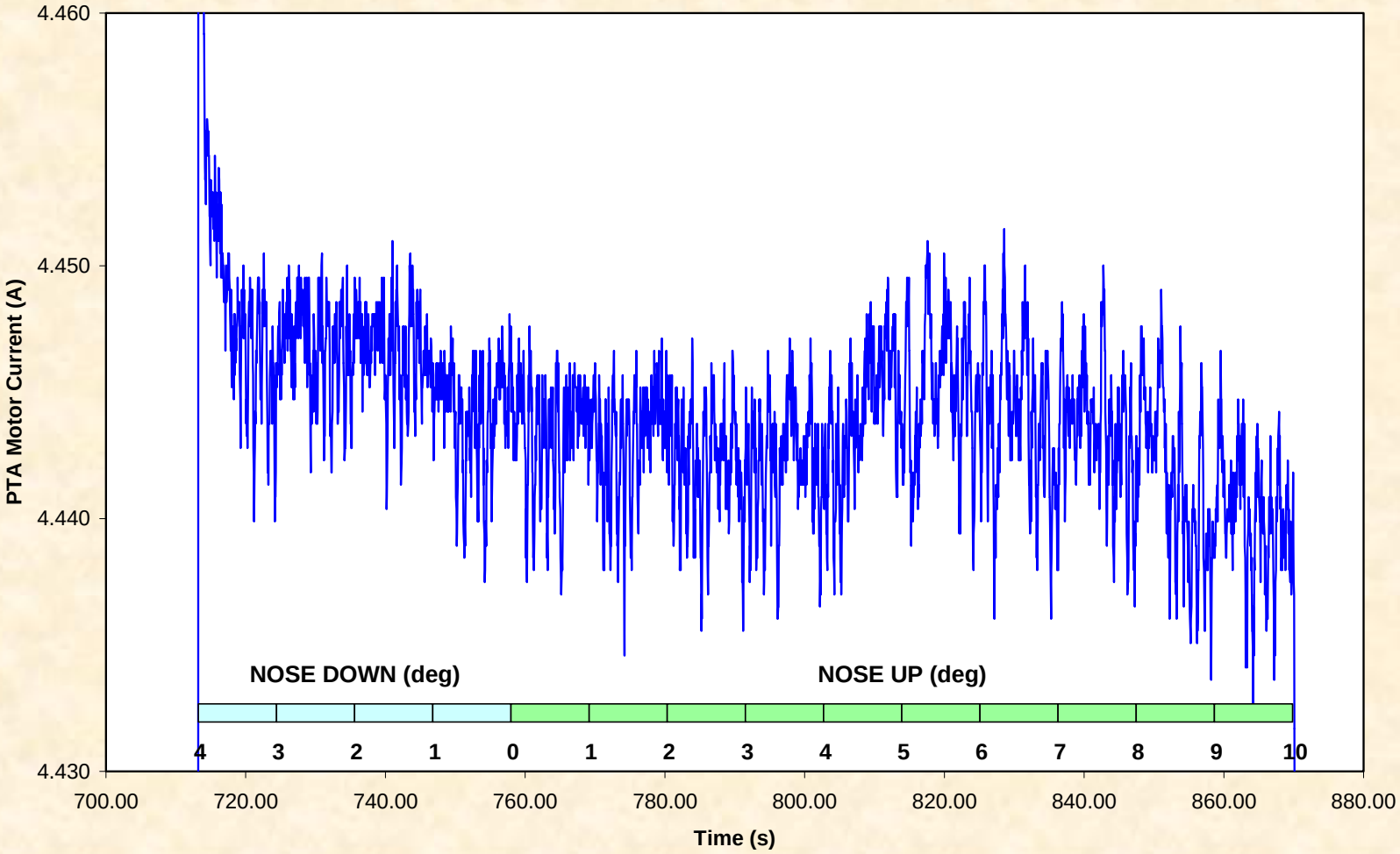
Examining the Second PTA Cycle, the Differences Between Idle Motor Current and PTA Engagement Current Can Be More Clearly Seen

Subtle RMS level variations can also be seen when the PTA is engaged



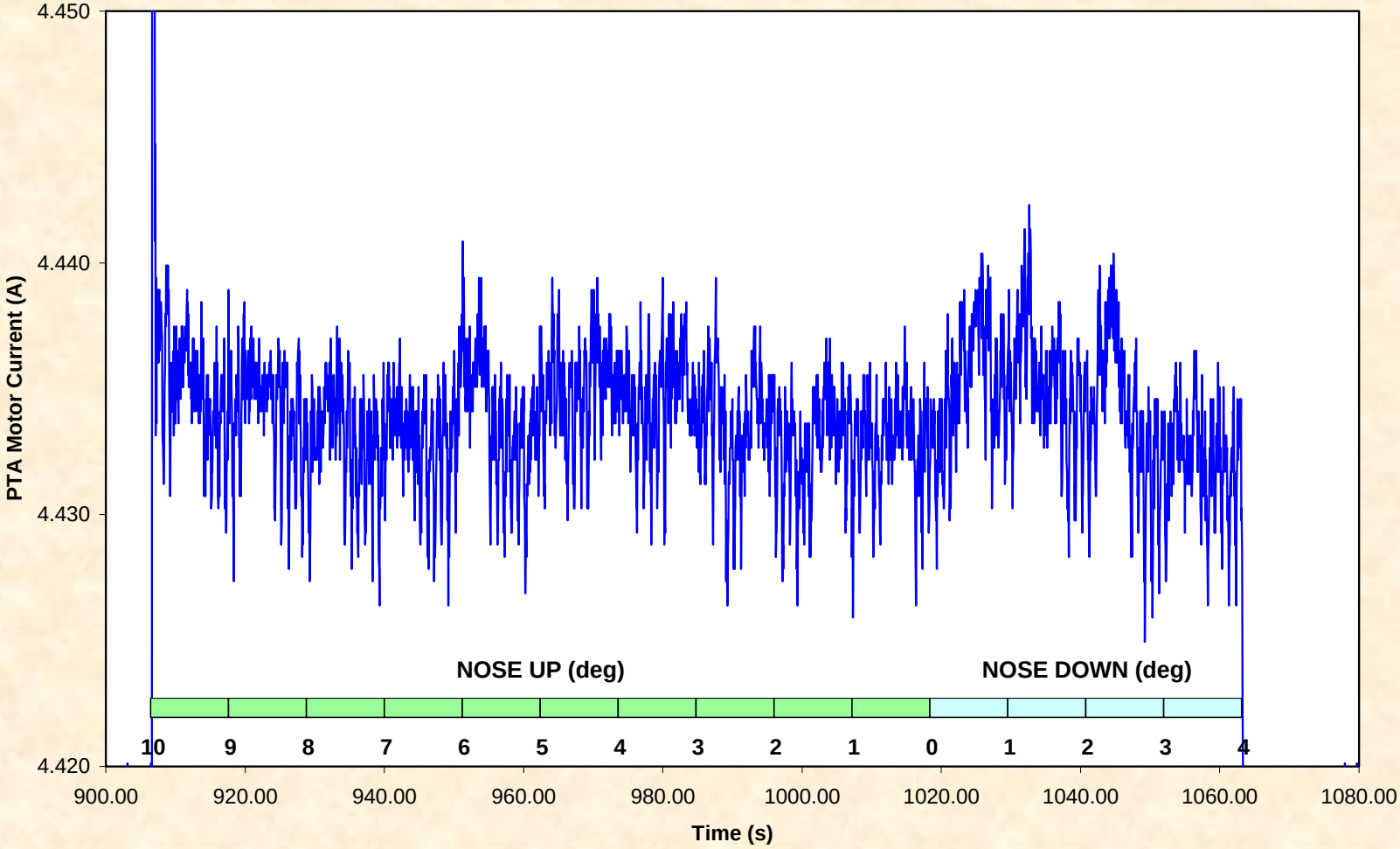
The PTA Current Fluctuations May Indicate Variations In Jack Screw Thread Condition

Second operation of the PTA in the nose up direction



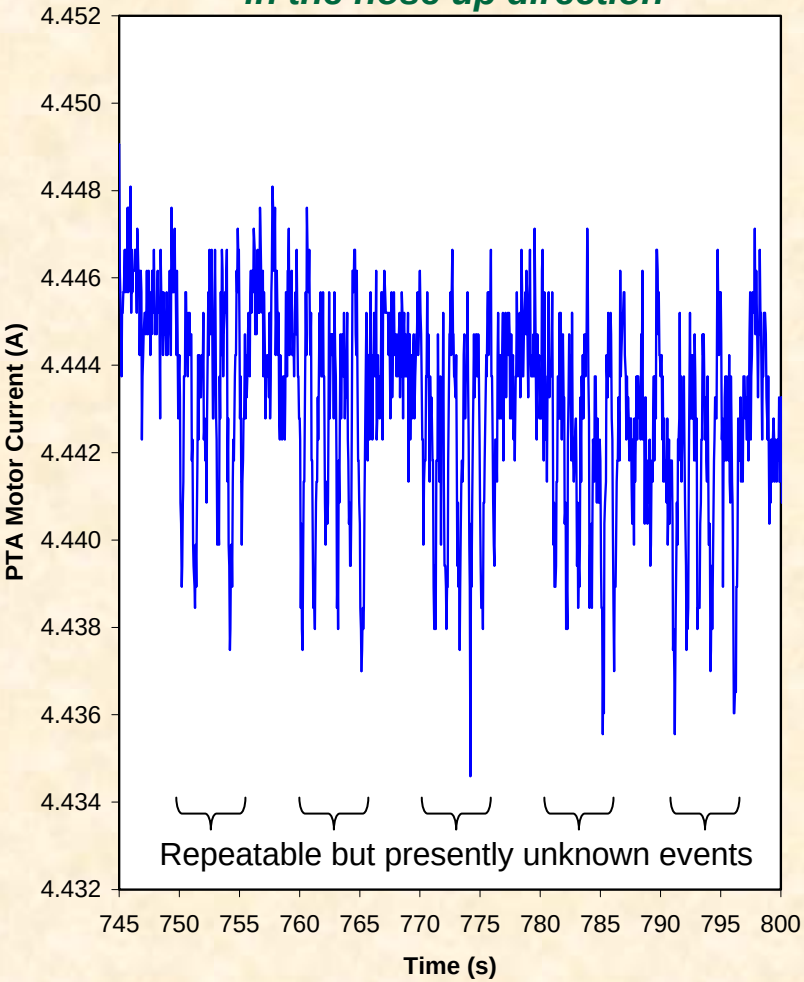
The PTA Current Fluctuations May Indicate Variations In Jack Screw Thread Condition (continued)

Second operation of the PTA in the nose down direction

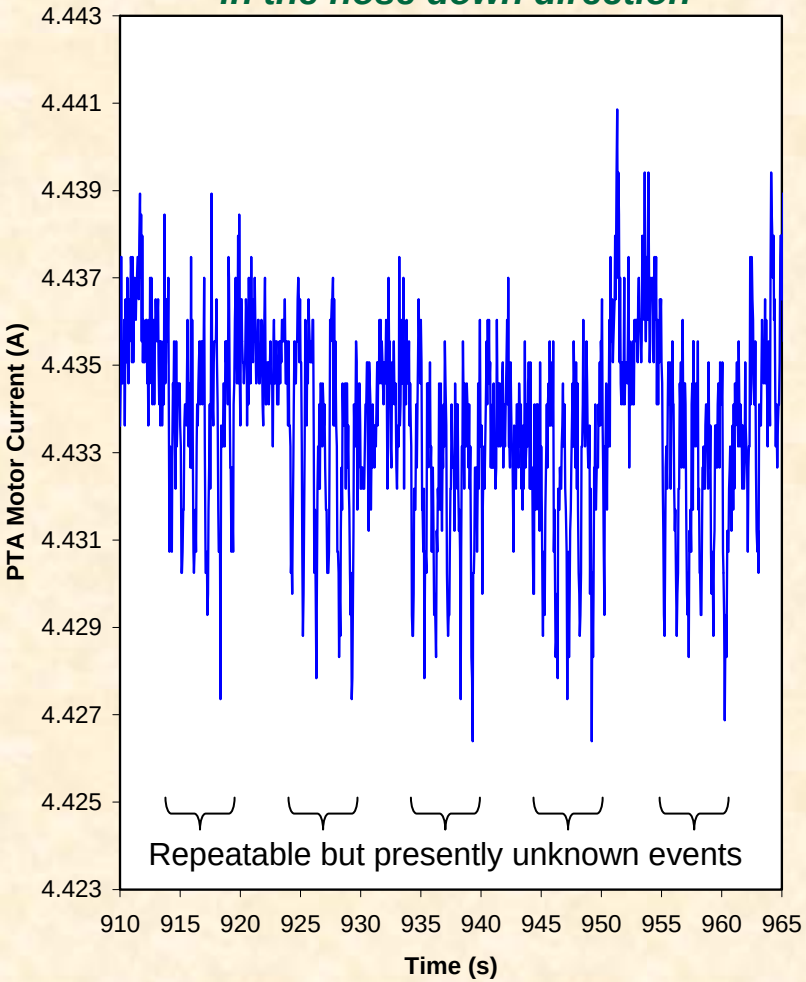


A Closer Look at the PTA Current Fluctuations Reveals Additional Repeatable Features

Second operation of the PTA in the nose up direction

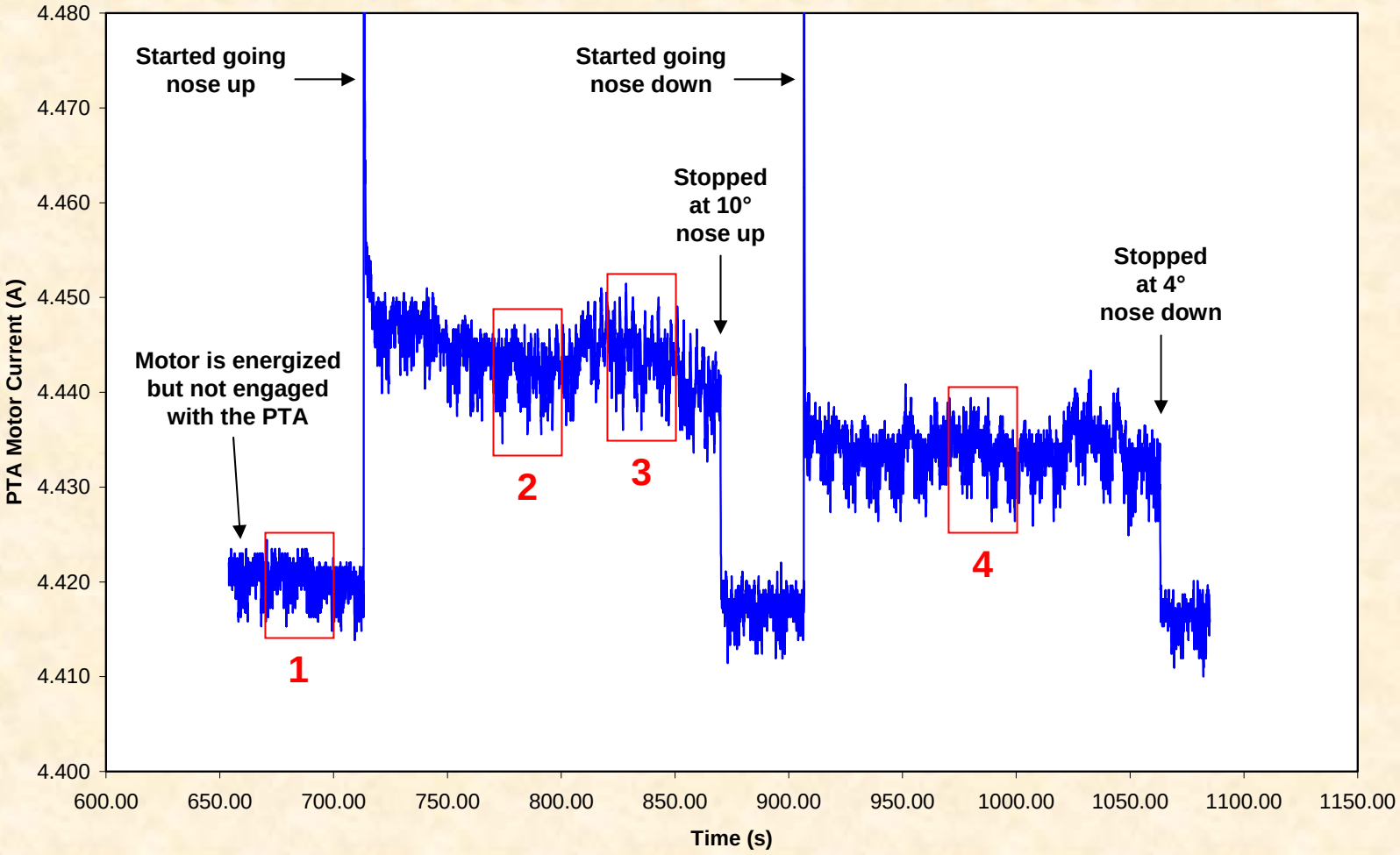


Second operation of the PTA in the nose down direction



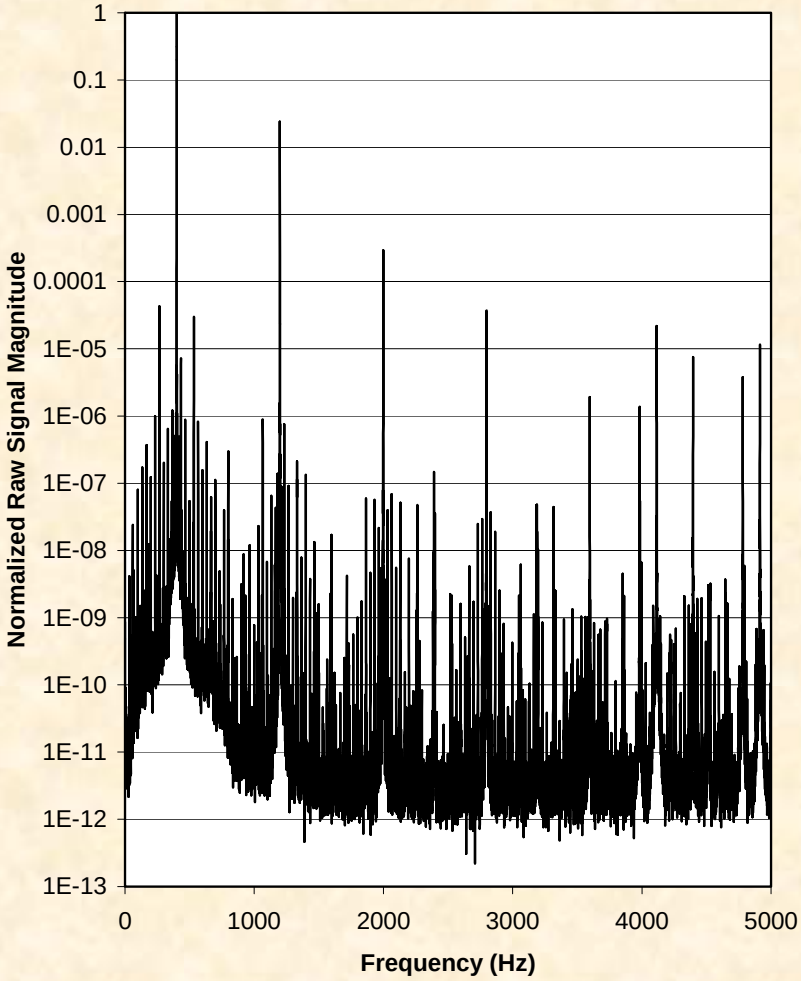
Segments of the PTA Motor Current Signal Were Analyzed in the Frequency Domain

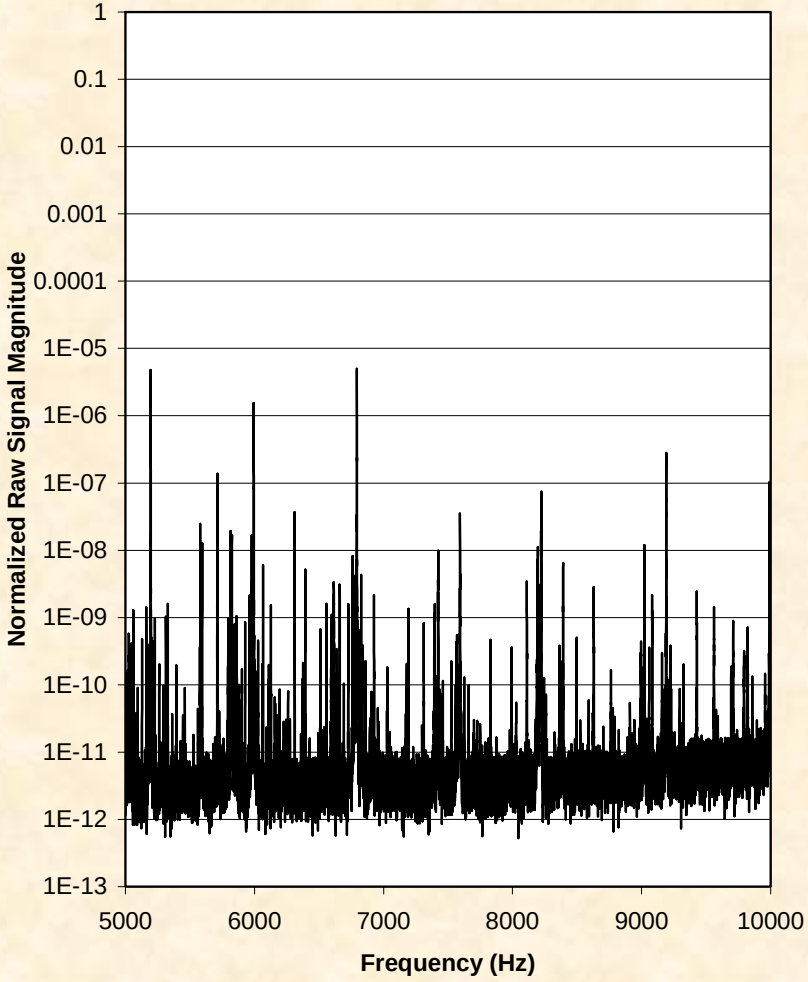
Four 30-second segments were selected



The Motor Current Spectrum Includes Numerous Peaks That Are Likely to Reflect the Condition of the Motor, Jackscrew, and Other Components

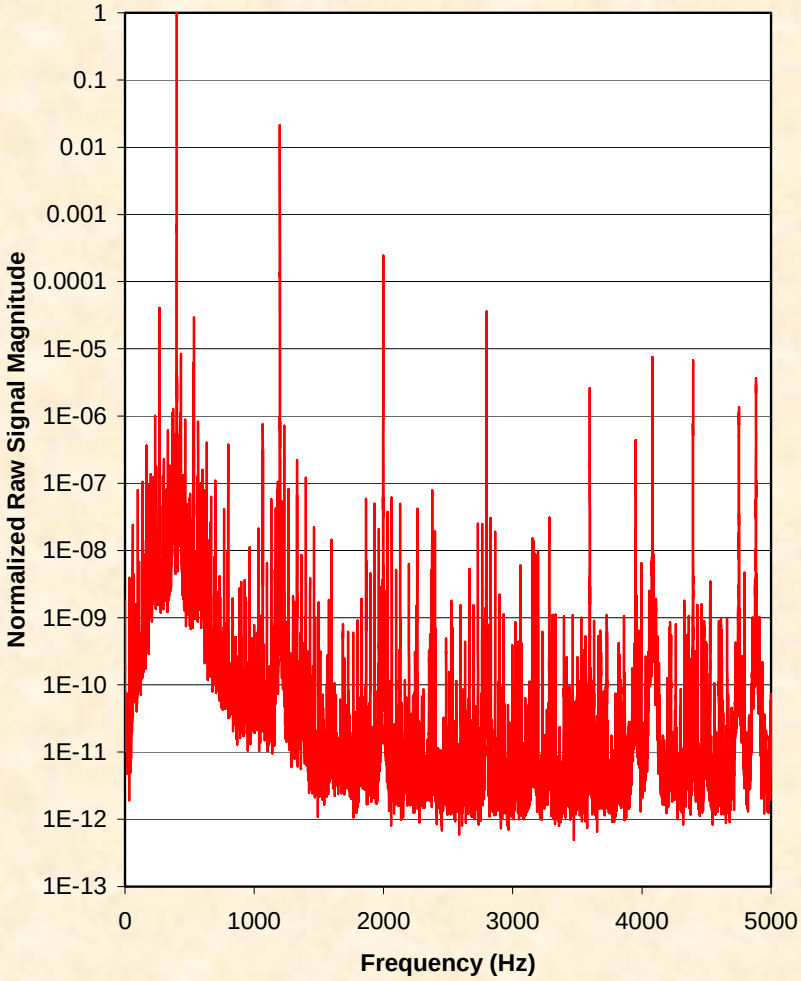
1 ***PTA not engaged (670 s - 700 s)***

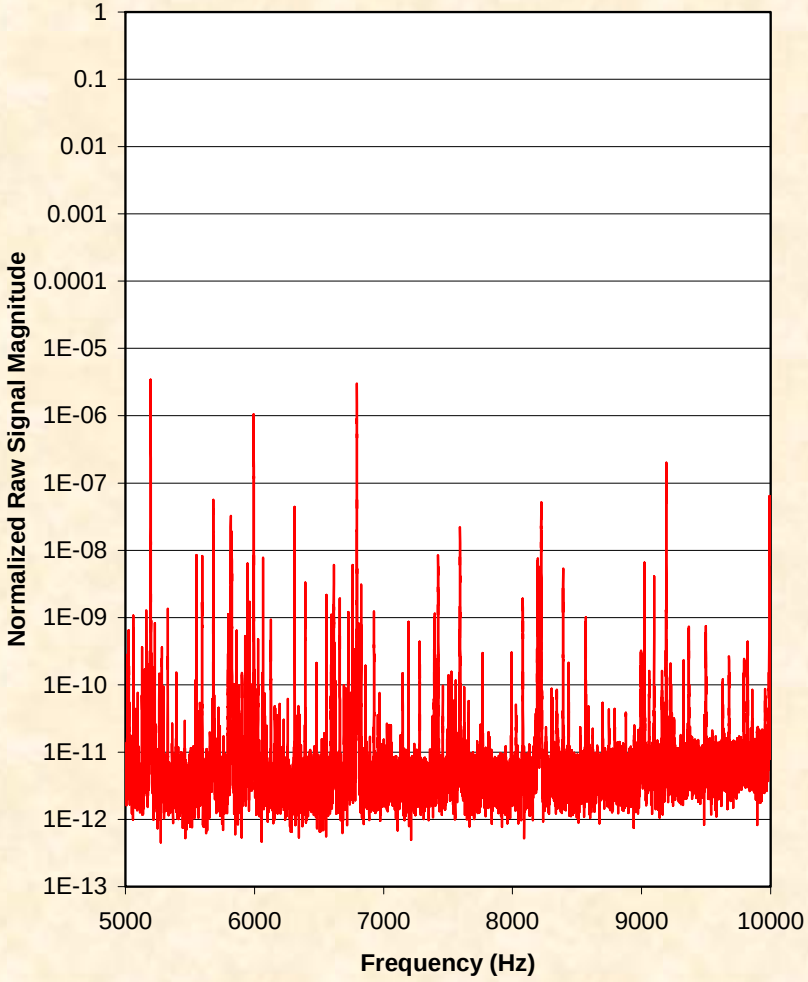




The Motor Current Spectrum Includes Numerous Peaks (continued)

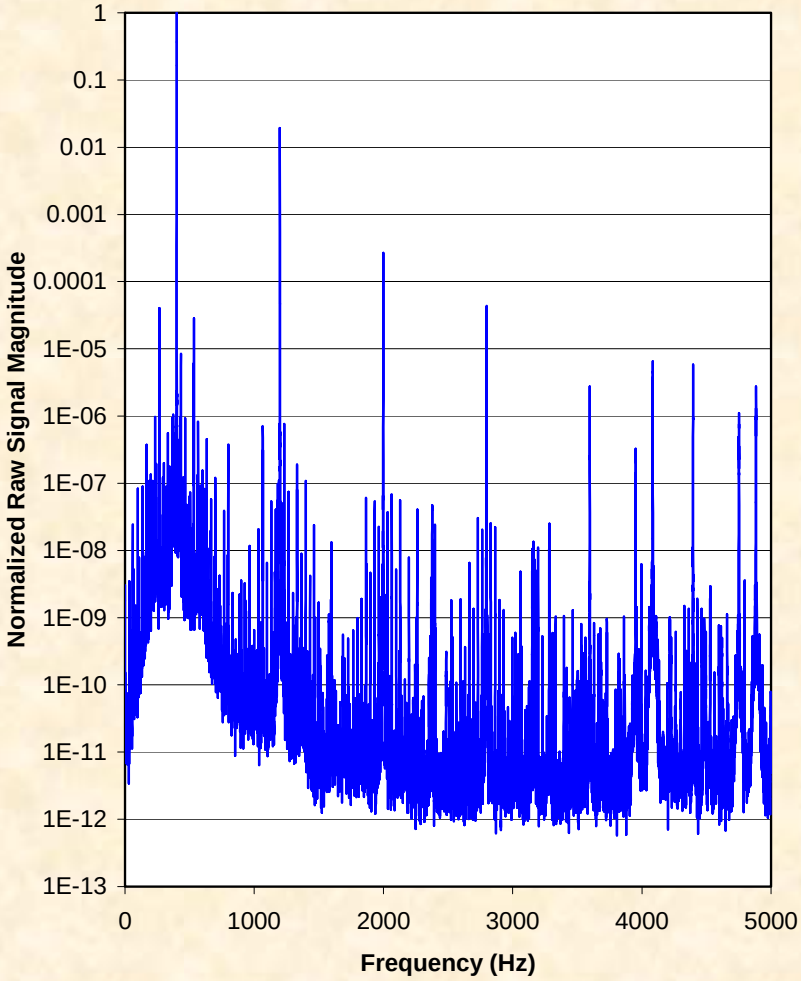
2 ***PTA going nose up (770 s - 800 s)***

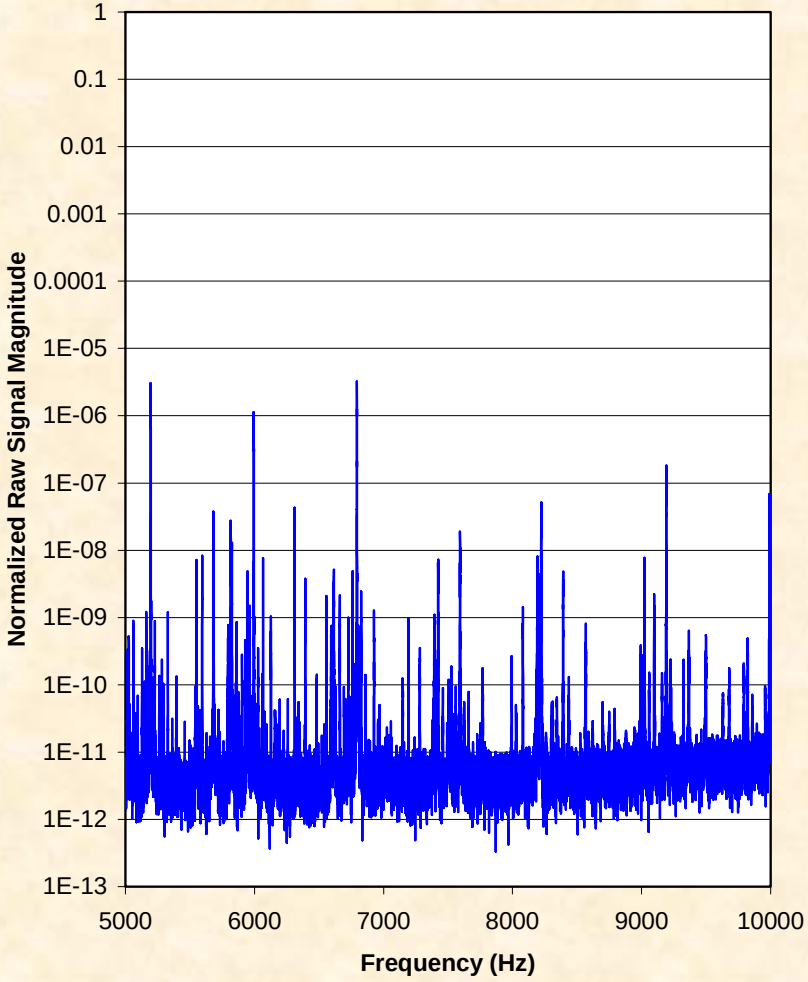




The Motor Current Spectrum Includes Numerous Peaks (continued)

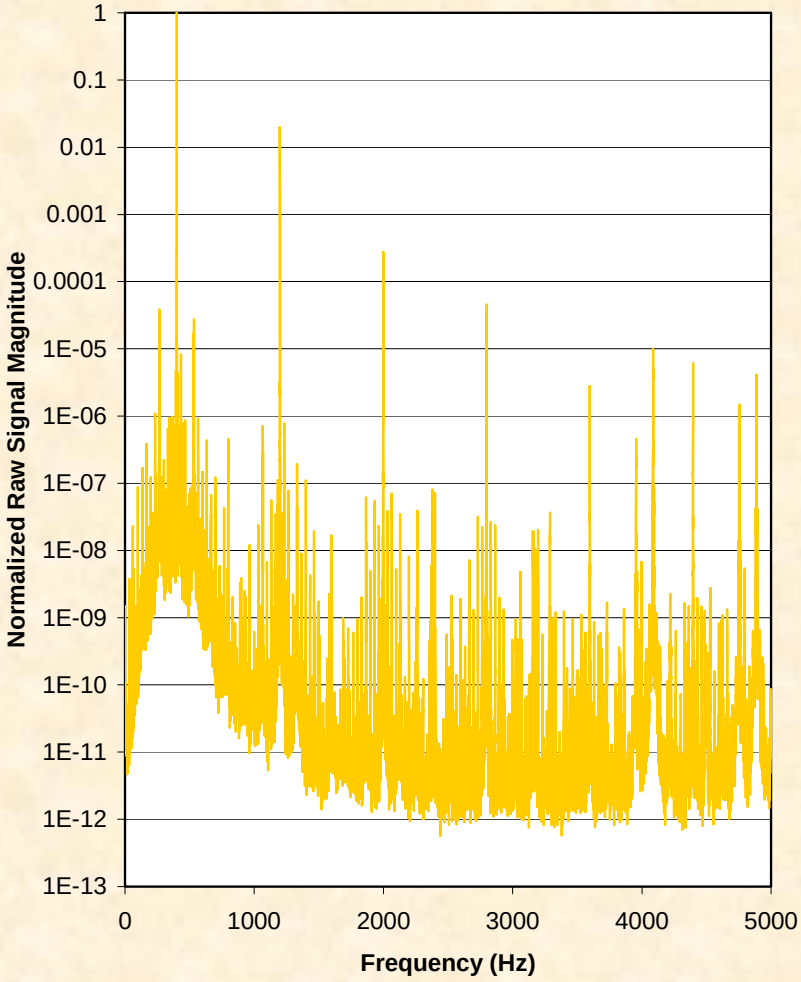
3 ***PTA going nose up (820 s - 850 s)***

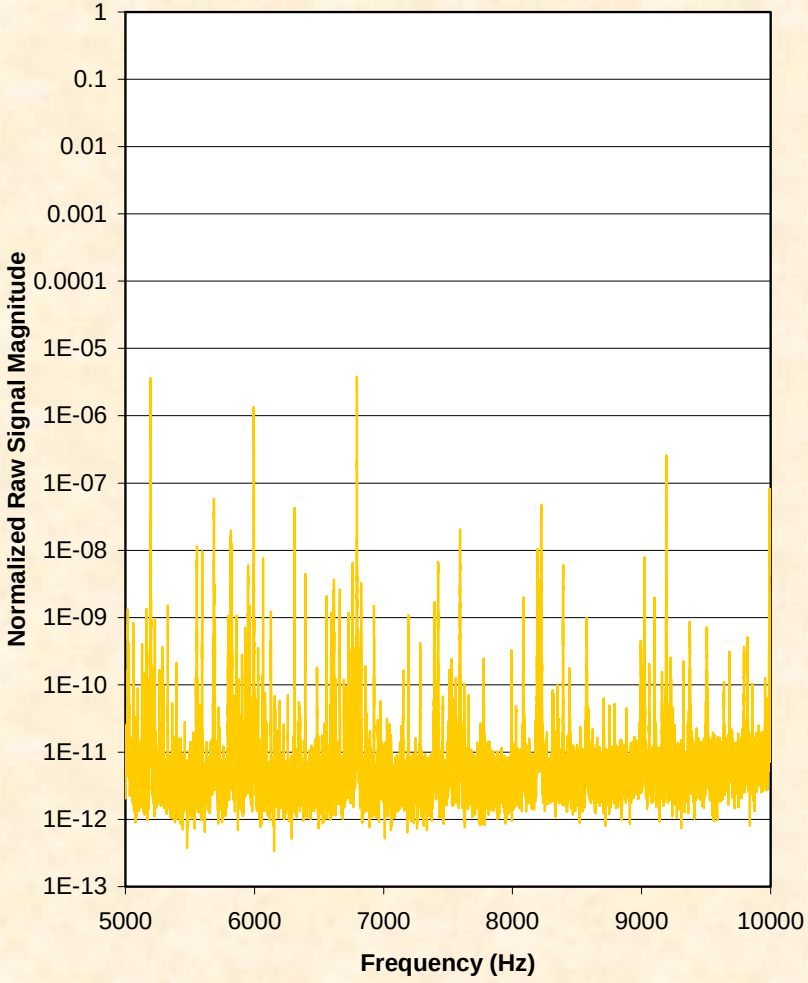




The Motor Current Spectrum Includes Numerous Peaks (continued)

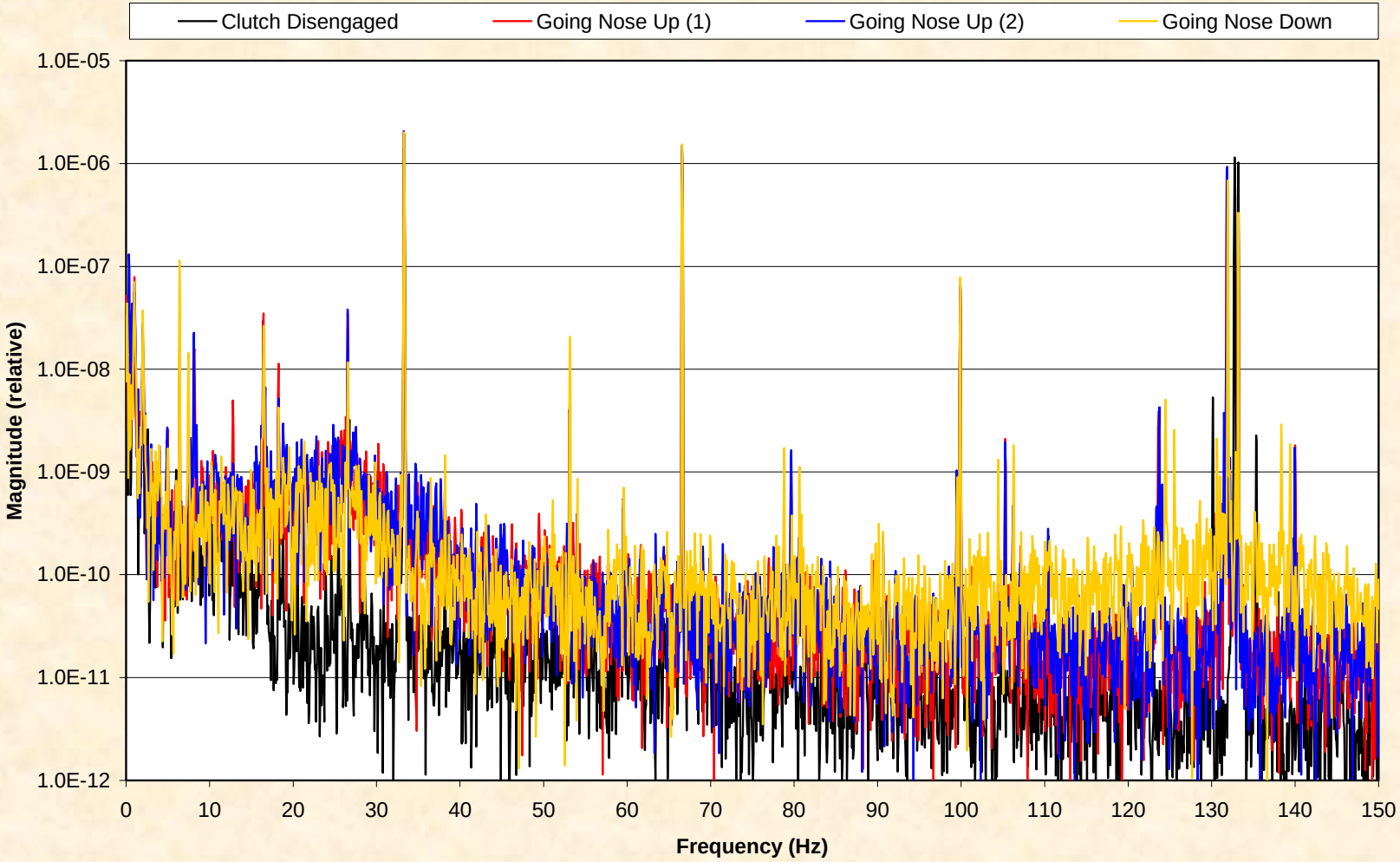
4 ***PTA going nose down (970 s - 1000 s)***





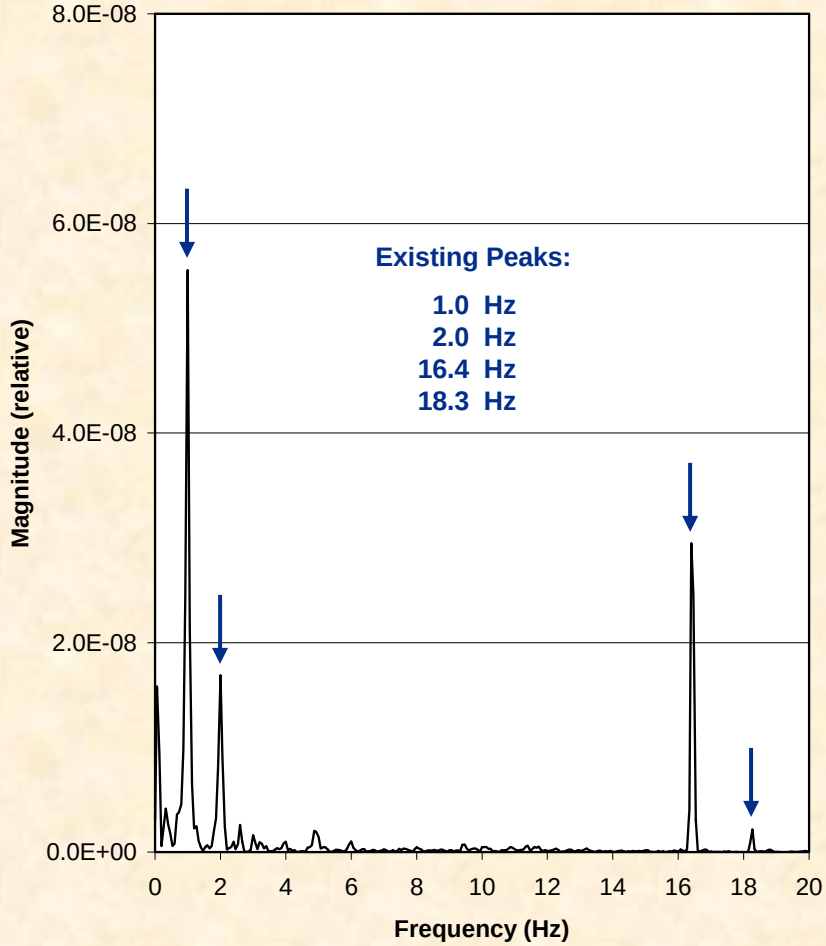
It Is Often Easier to Analyze Demodulated Motor Current Signals

Comparison of demodulated PTA motor current signals

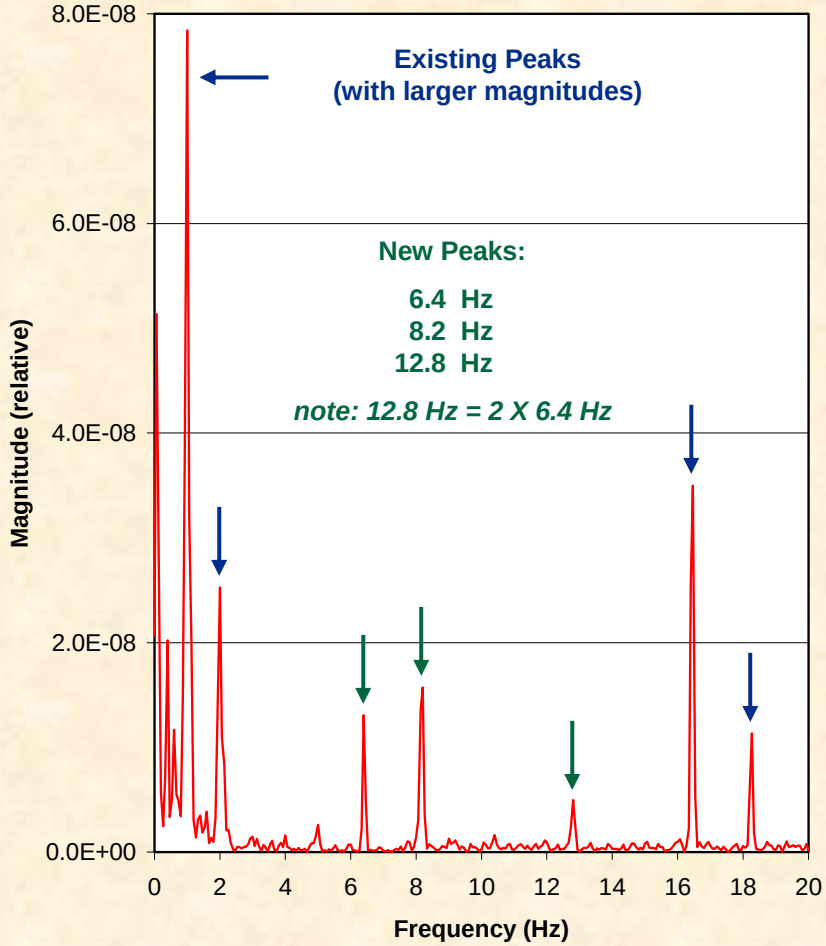


While Some Frequency Components Are Already Present in the Demodulated Signals Before the Motor Is Engaged With the PTA, Several New Peaks Are Created After Engagement

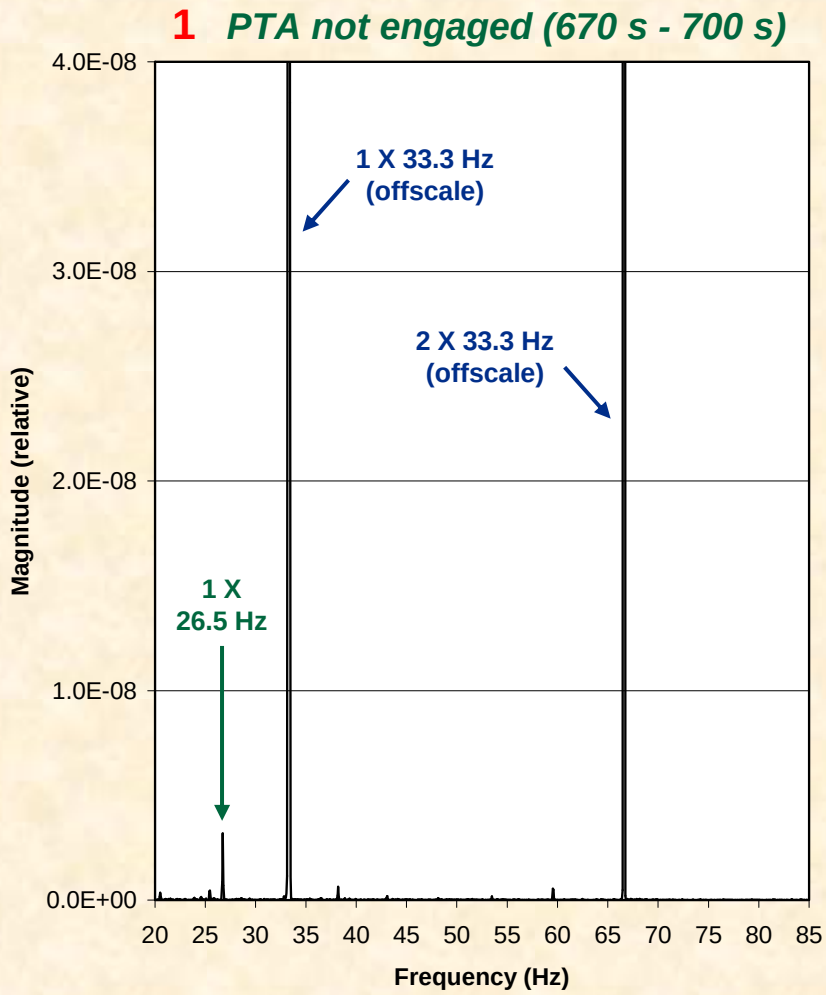
1 *PTA not engaged (670 s - 700 s)*

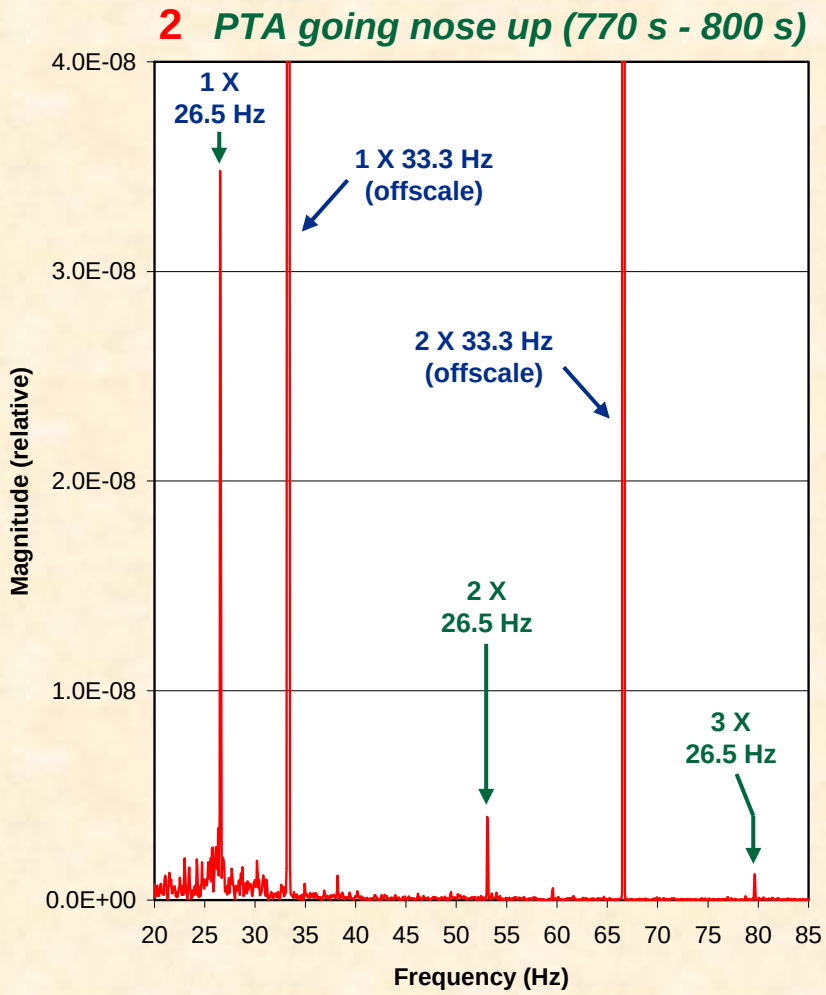


2 *PTA going nose up (770 s - 800 s)*



Large Peaks Are Observed in the Demodulated Signals at 26.5 Hz, 33.3 Hz, And at Multiples of Those Frequencies





Some Additional Information About the C-141 Pitch Trim Actuator (PTA) Motor Is Now Known:

Rotor speed = 7600 RPM single full load

Winding type = induction-squirrel cage

Power rating = 2.0 hp

Shaft diameter = 0.65 in.

- ***The motor is therefore a 6-pole design (like the fuel pump motor).***

- ***Based on an analysis of demodulated signals, it appears that the motor speeds during the test may have been:***

Before motor is engaged with PTA:	***7964 RPM ****
Going in nose up direction:	***7910 RPM ****
Going in nose down direction:	***7917 RPM ****

* ***The PTA was tested on the ground, without the significant aerodynamic loading that is present during flight. Additional testing is needed to confirm the identity of the motor speed peaks.***

Preliminary Conclusions:

- C-141 Pitch Trim Actuator (PTA) motor current signals were easily obtained in the cockpit.
- Only a small increase in RMS motor current (~ 25 mA) was detected when the PTA was engaged. This is only about one-half of one percent of the idle current for this motor.
- Subtle variations in RMS current were observed during PTA stroking. These variations are believed to be directly related to jackscrew thread condition.
- The motor current spectrum contains numerous peaks that are likely to reflect the condition of the motor, jackscrew, and other components.
- PTA Motor speed can apparently be detected from the motor current frequency spectrum.
- This preliminary test was performed while the C-141 was on the ground. Under these conditions, the horizontal tail wing (and thus the PTA) were not subjected to the large aerodynamic forces that accompany flight. These forces are expected to exaggerate the motor current signature features that were observed in the preliminary test. Testing of a PTA during flight would be relatively non-intrusive using ESA.
- Based on this preliminary test, the PTA is an ideal component for developing ESA-based condition assessment instrumentation. ORNL has considerable experience in applying ESA as a diagnostic technology for motor-operated, rising-stem valves, which have mechanical features similar to those of the C-141 PTA.
- PTA testing capability can be added to the ESA platform presently being used as a Fuel Pump Condition Monitor (FPCM).