AN AIRCRAFT MODAL SUPPRESSION YAW DAMPER SYSTEM

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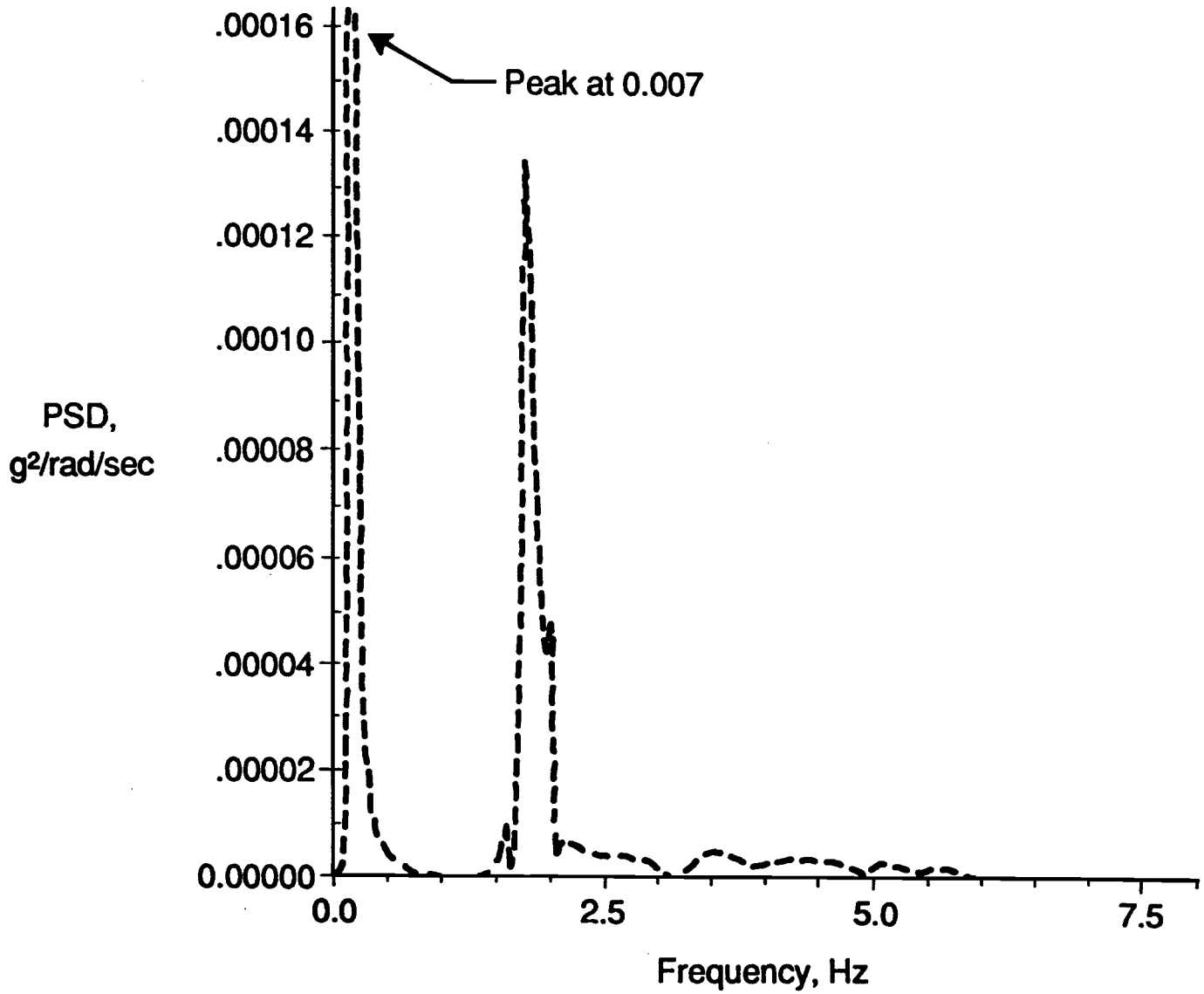
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Objectives of Modal Suppression Yaw Damper

- Control Dutch Roll Response
- Provide Good Turn Coordination
- Suppress Flexible Body Modes
  - Improve Lateral Ride Comfort

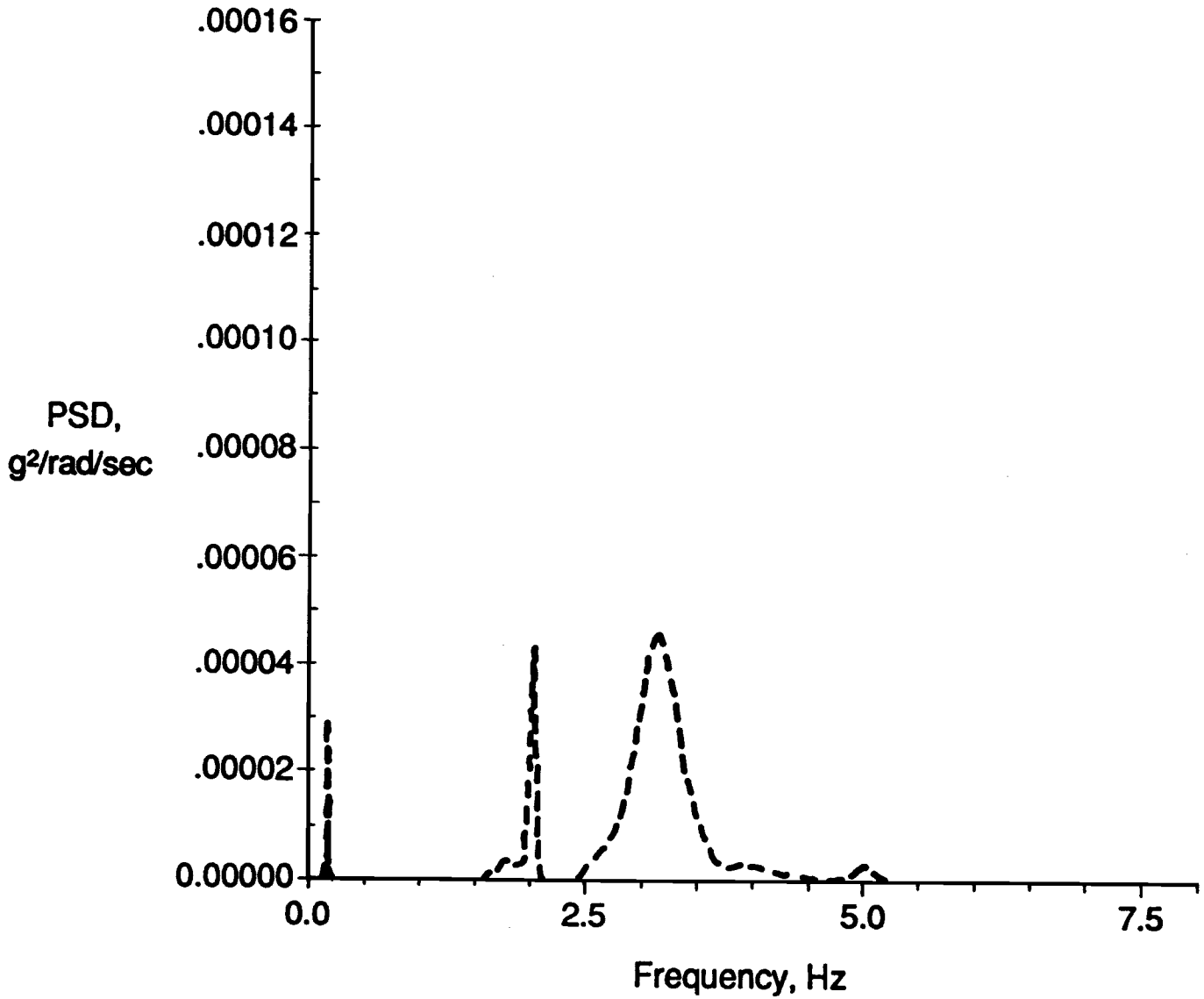
747

PSD of the Lateral Acceleration at the Aft Galley



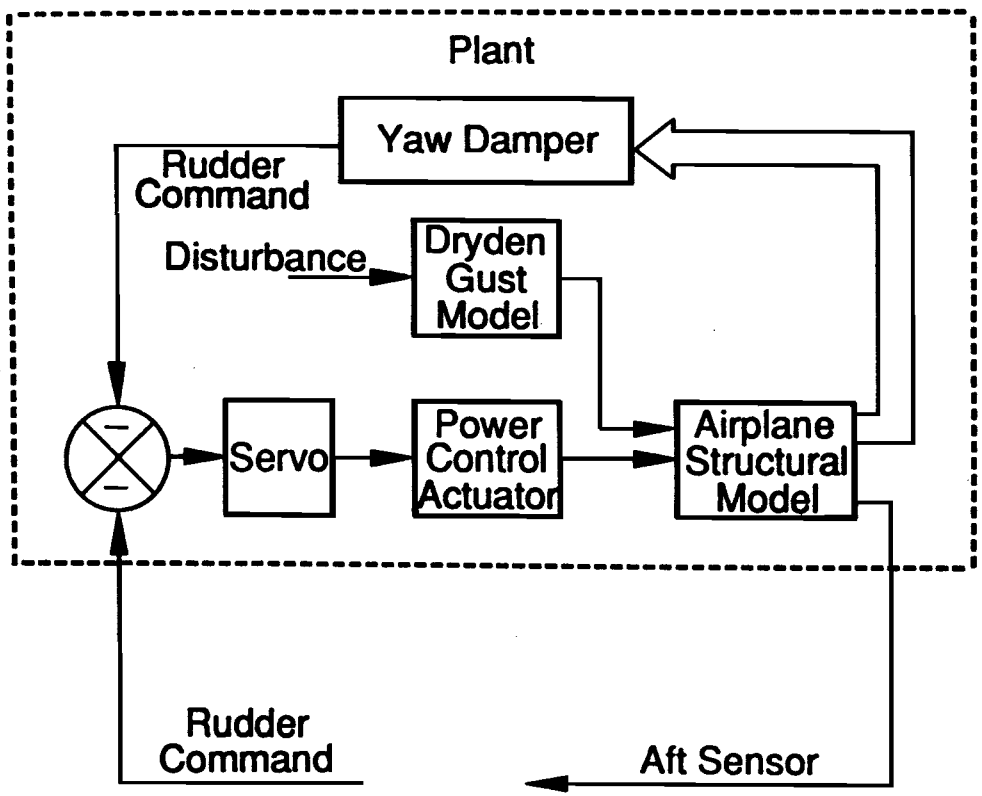
AAC-3

747
PSD of the Lateral Accleration at the Pilot Station

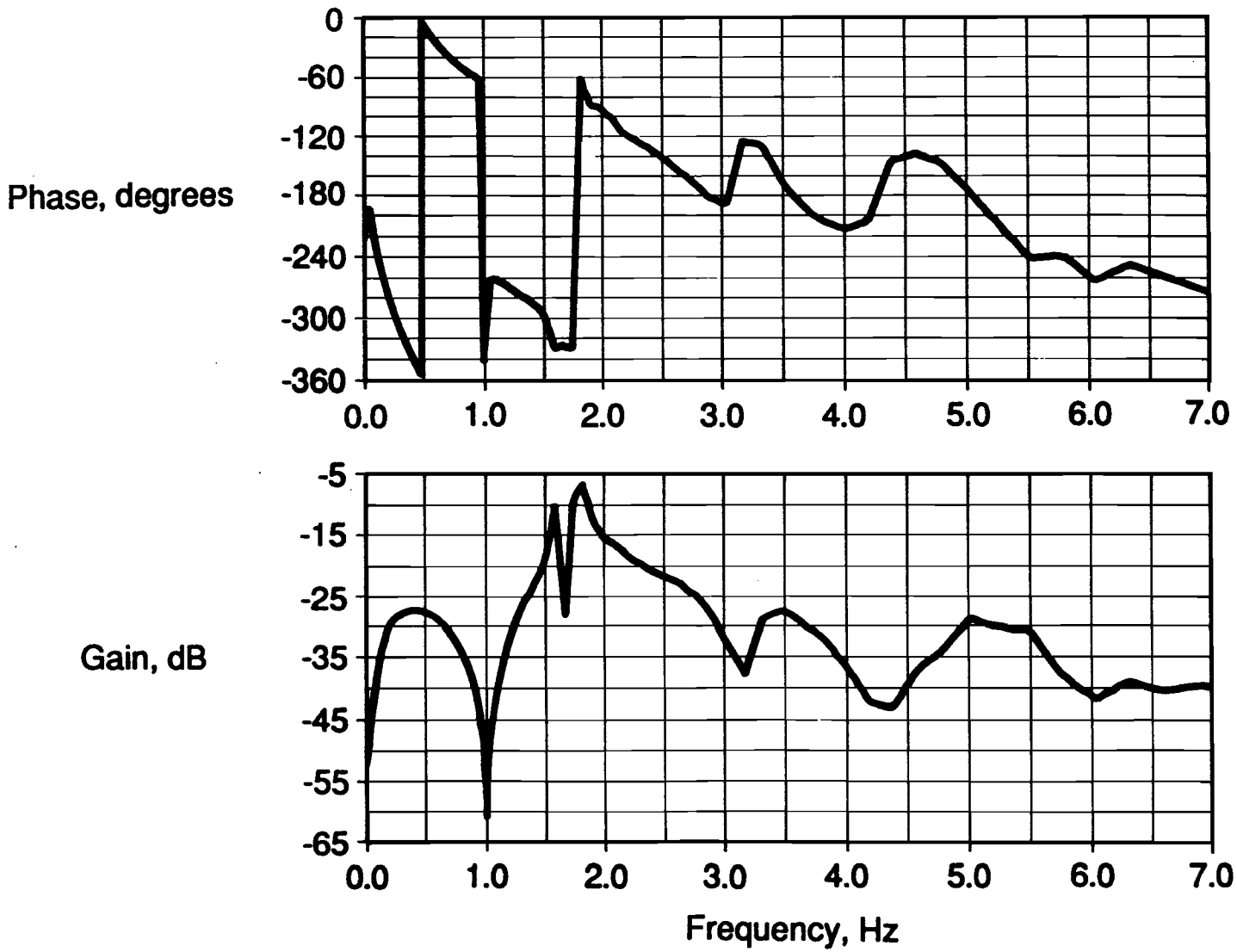


AAC-4

747
Plant Model for Aft Filter Design



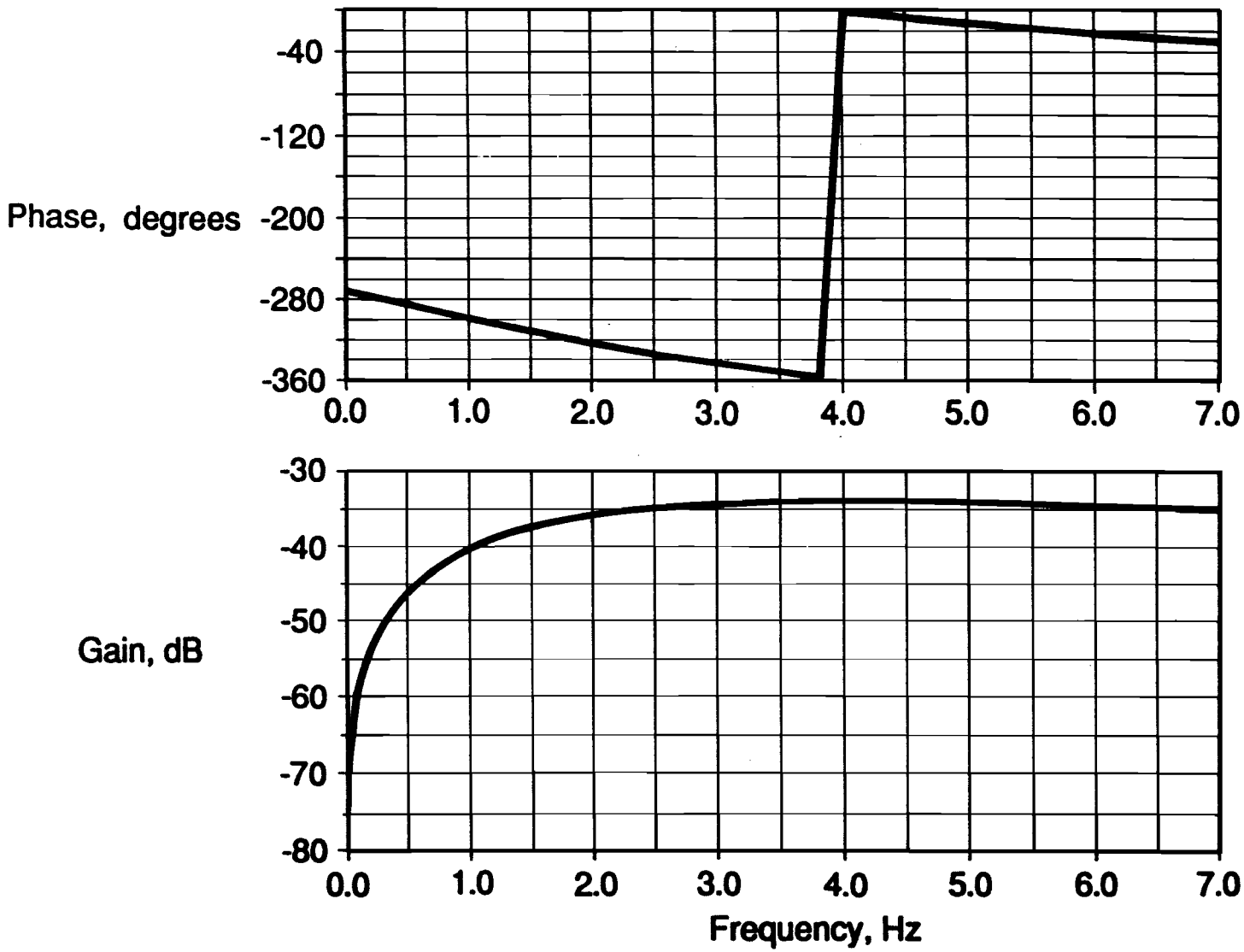
747
Transfer Function
Rudder Command to Aft Galley Sensor



AAC-6

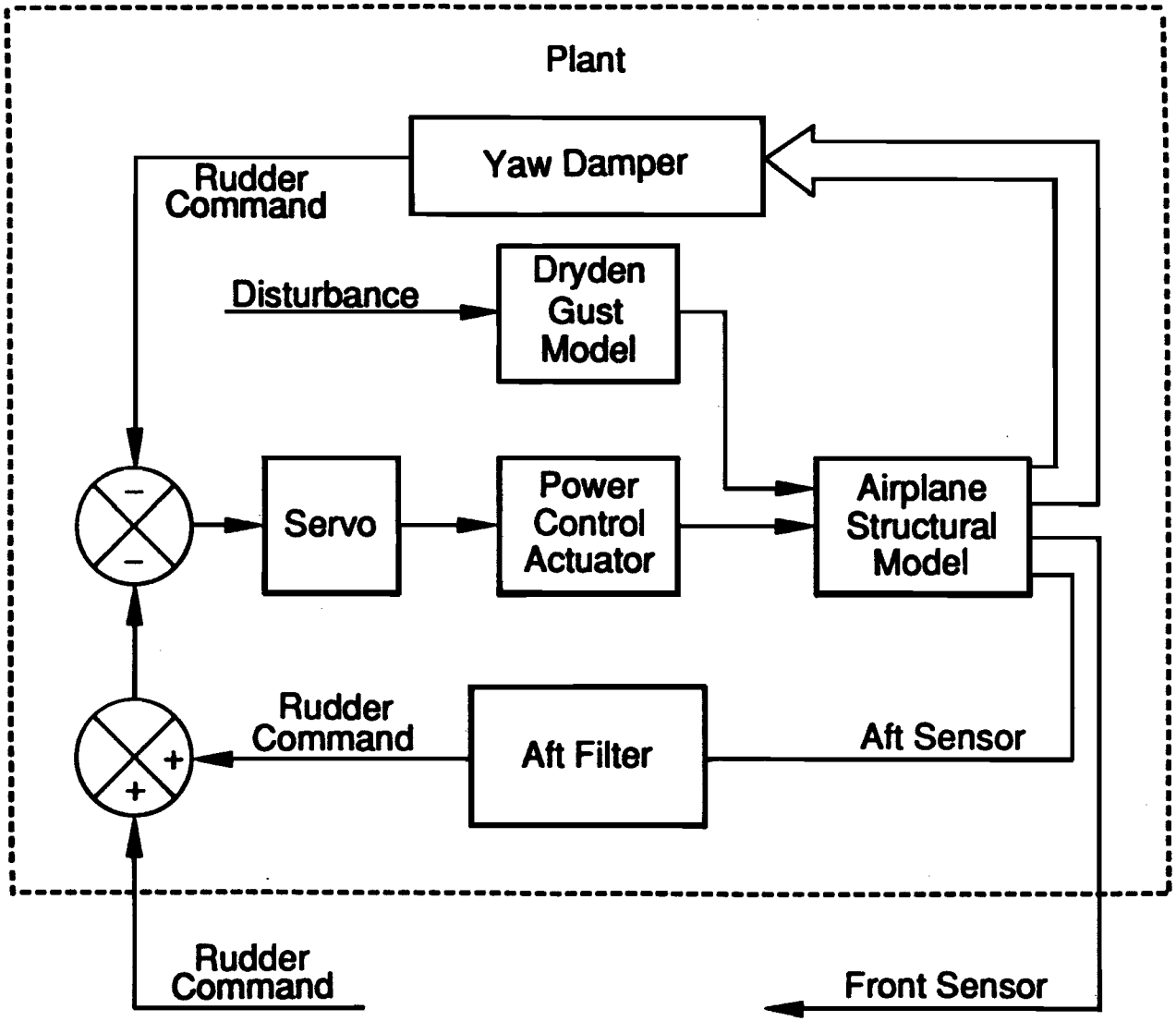
747

Transfer Function for the Aft Cabin Sensor Filter

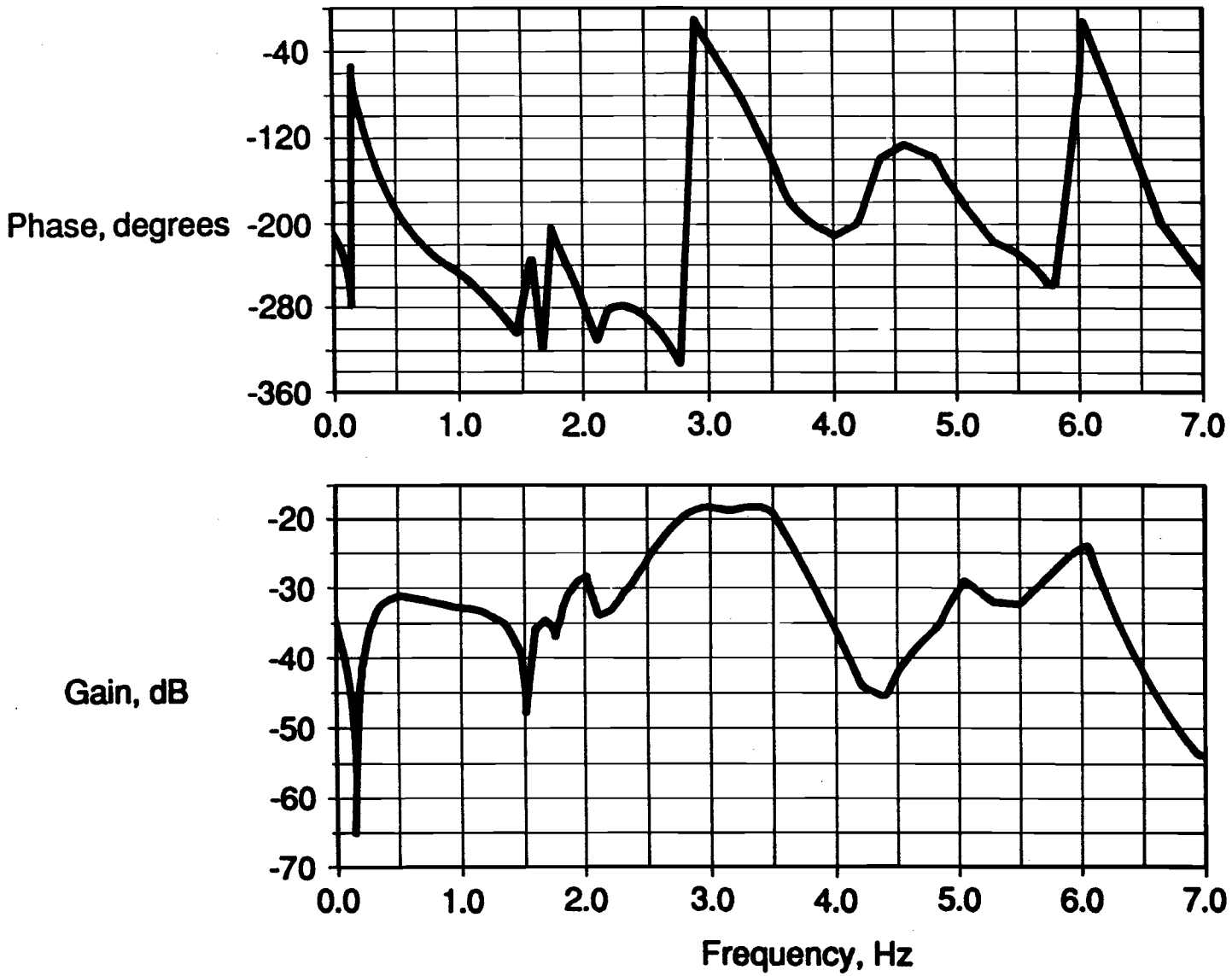


AAC-7

Plant Model for Pilot Station Filter Design

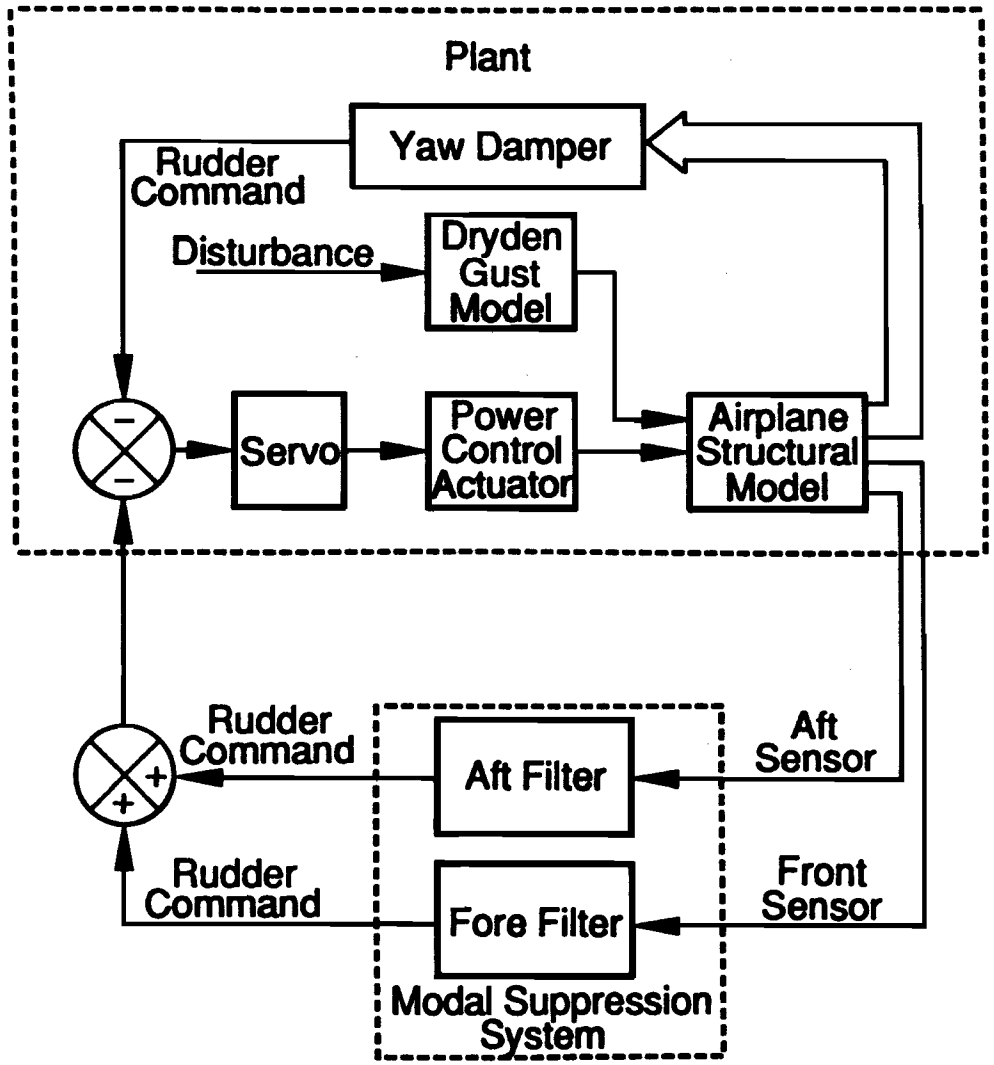


747
Transfer Function
Rudder Command to Pilot Station Sensor



AAC-9

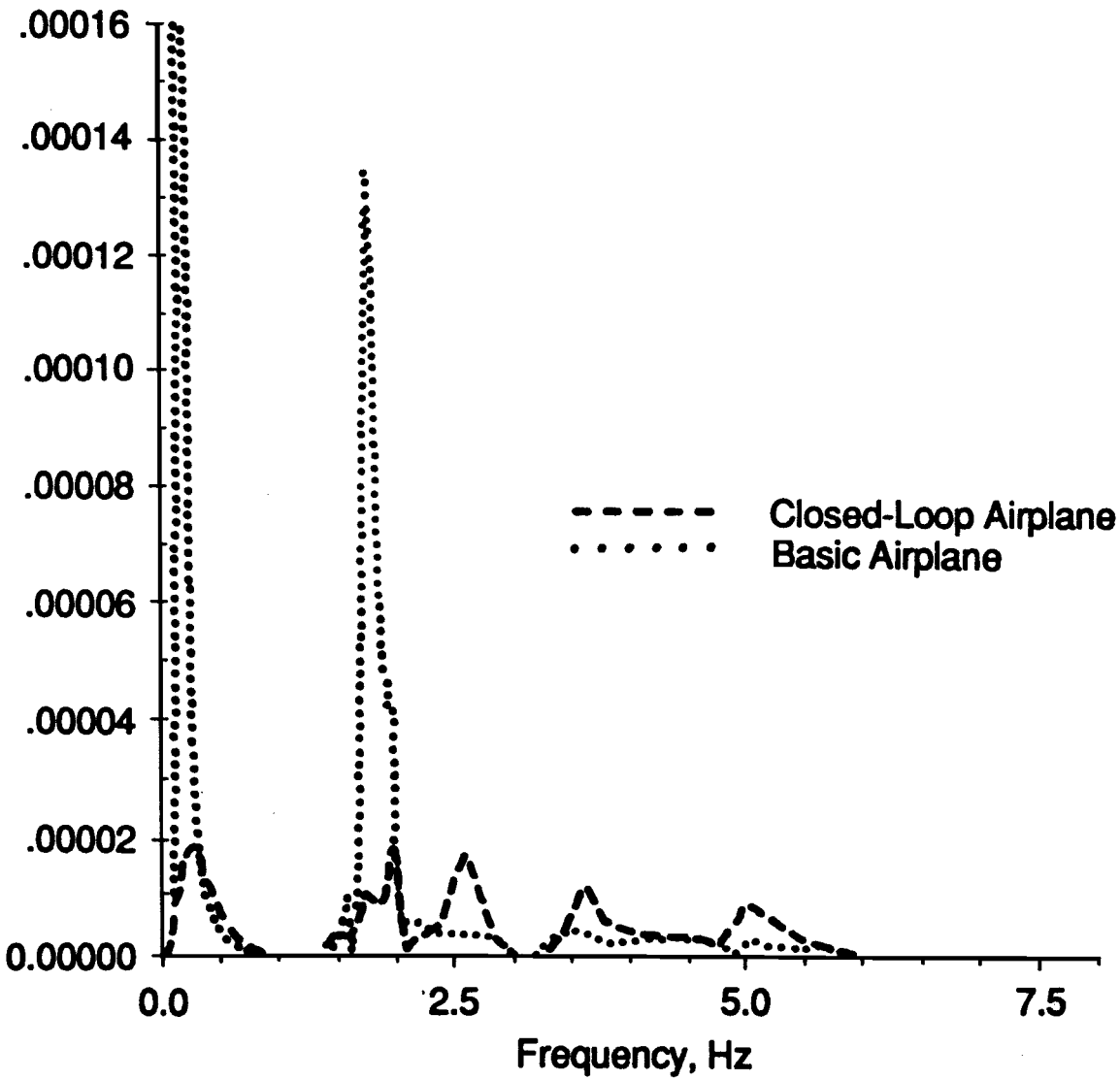
747
Closed-Loop System



AAC-10

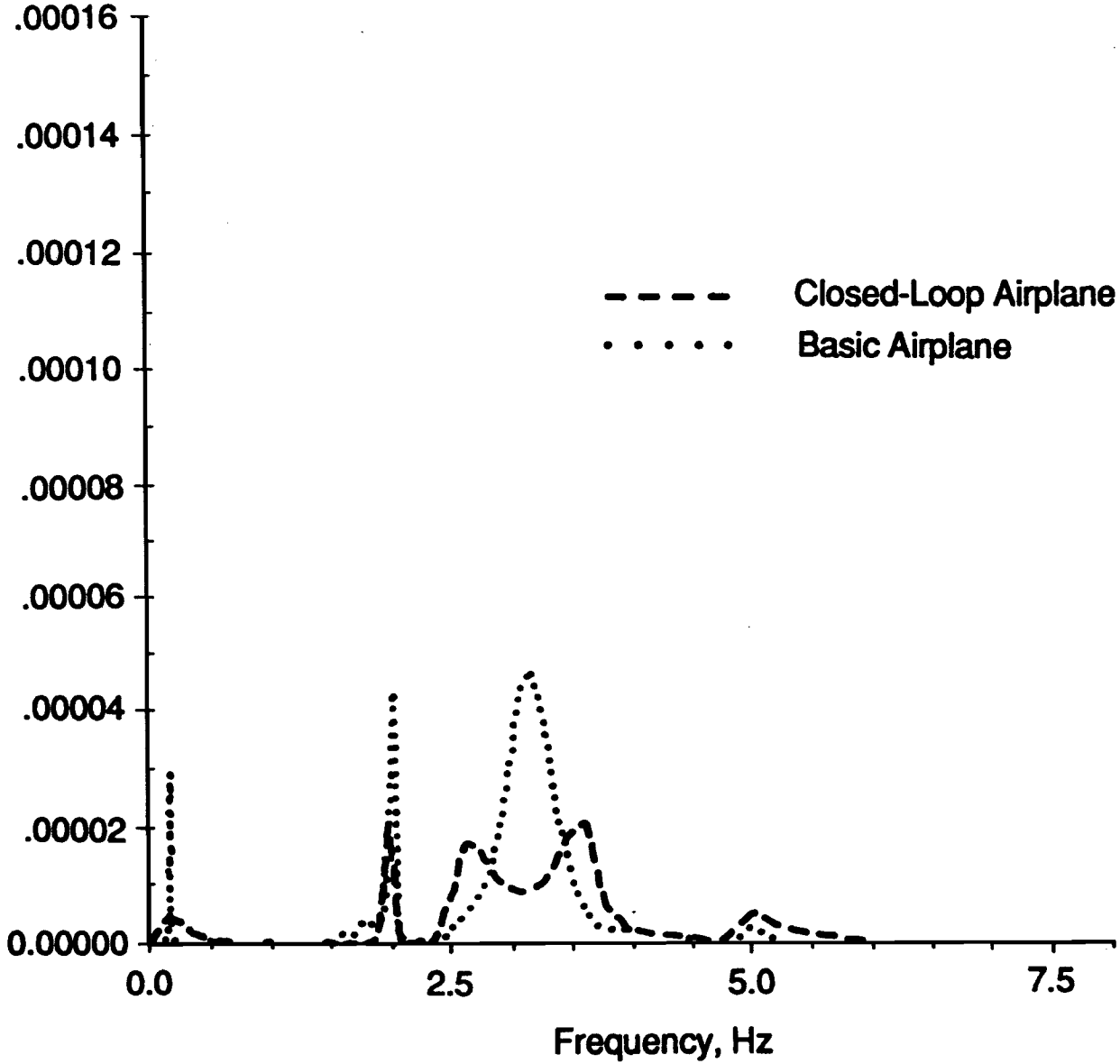
747

PSD of the Lateral Acceleration at the Aft Galley



AAC-11

PSD of the Lateral Acceleration at Pilot Station



747-400 / PW4000 (RT401)
Modal Suppression Yaw Damper Flight Test 4-15
6 July 1988 (15:14:00)

- **Airplane Configuration**

  - **Typical Revenue Payload with FWD CG**

    - OEW 365.8 K @ 26.1 % MAC
    - ZFW 402.9 K @ 17.6 % MAC
    - T/O GW 685.0 K @ 10.0 % MAC
    - @ Test Condition 586.5 K @ 12.8 % MAC

  - **Fuel Loading**

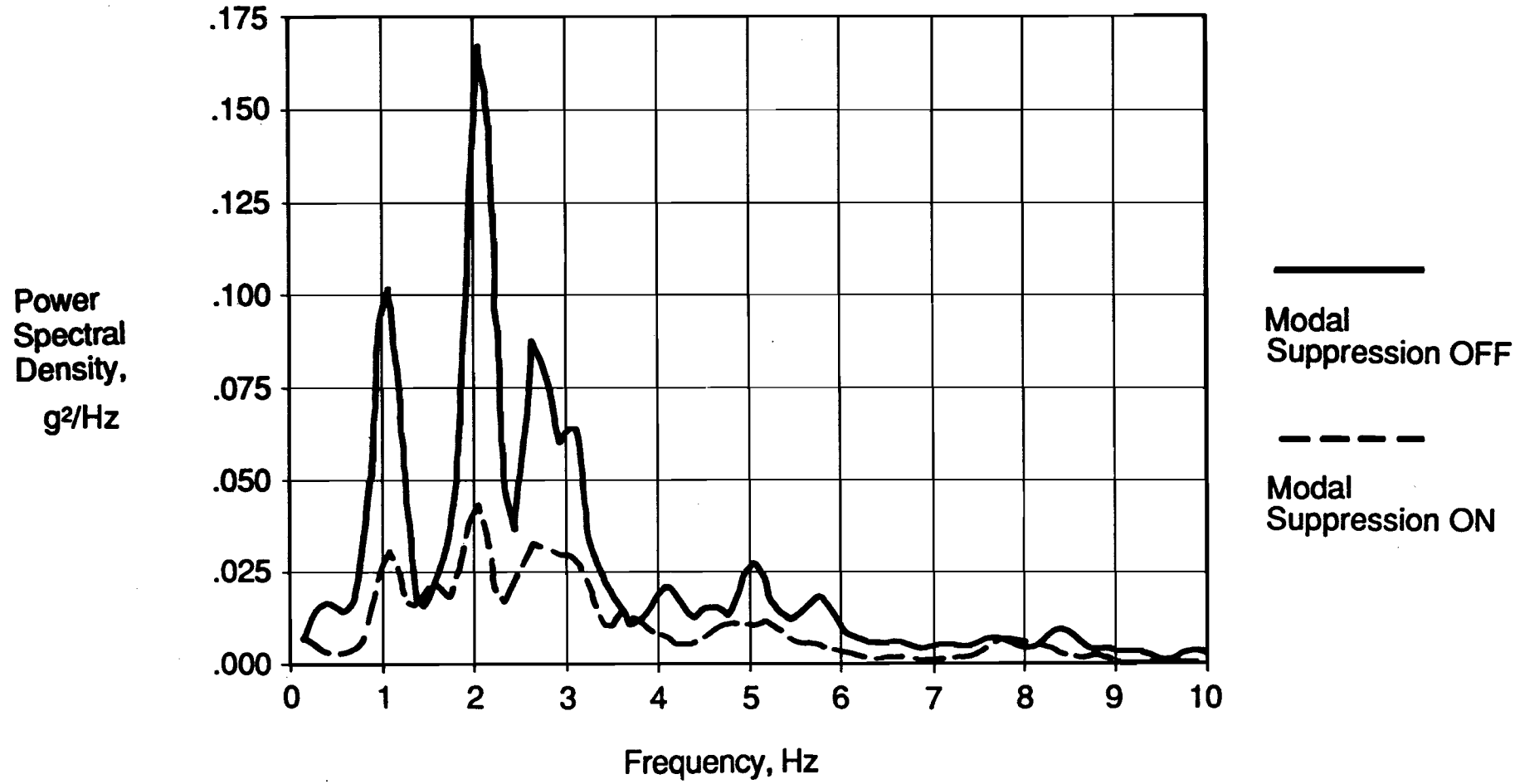
	T/O (% Full)	Flight Condition (Approx.)
Center Wing	45	~45
Main #1	100	~100
Main #2	100	<50
Main #3	100	<50
Main #4	100	~100
Res #2	0	0
Res #3	0	0
Stabilizer	0	0

  - **Flight Condition** (Turbulence)

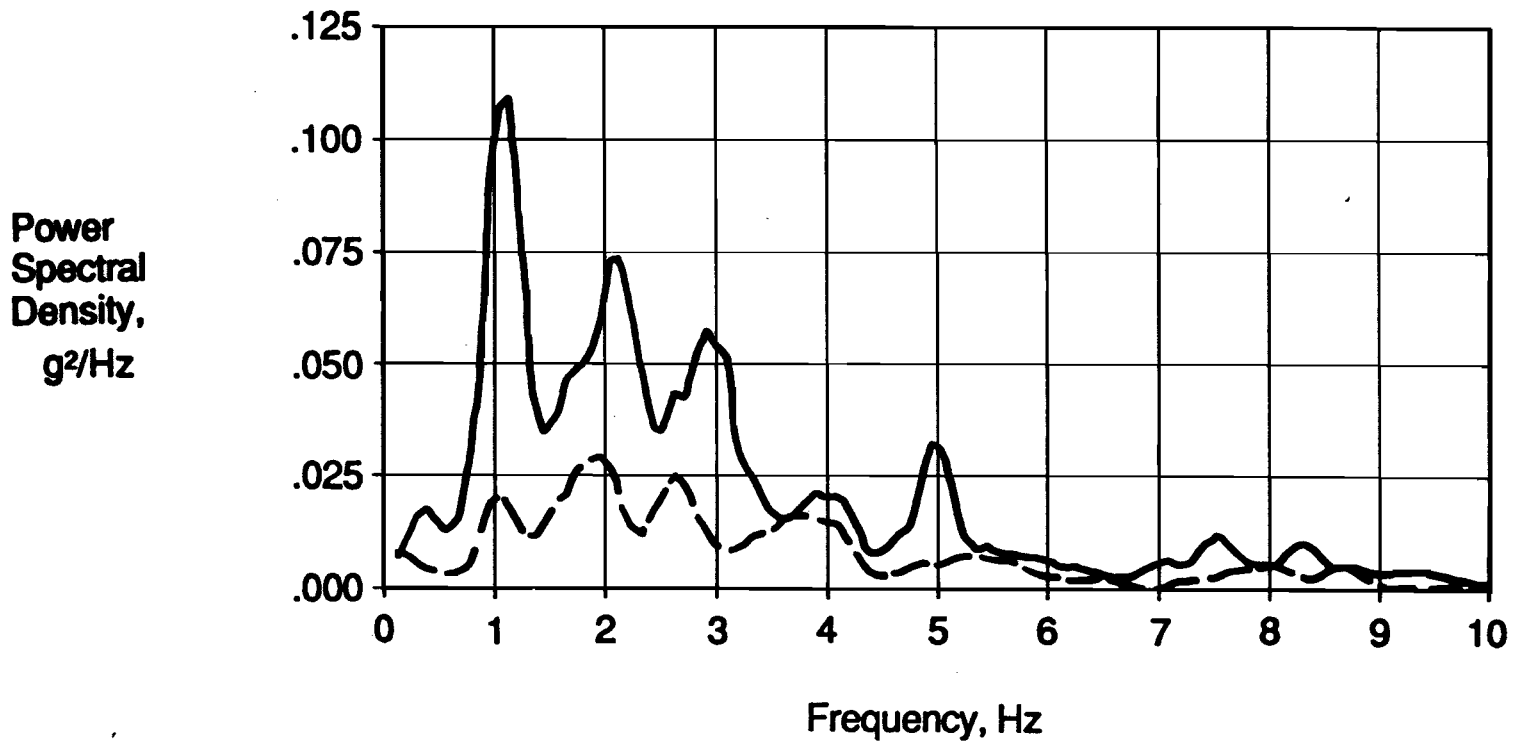
    M = .45

    h = 8000 ft

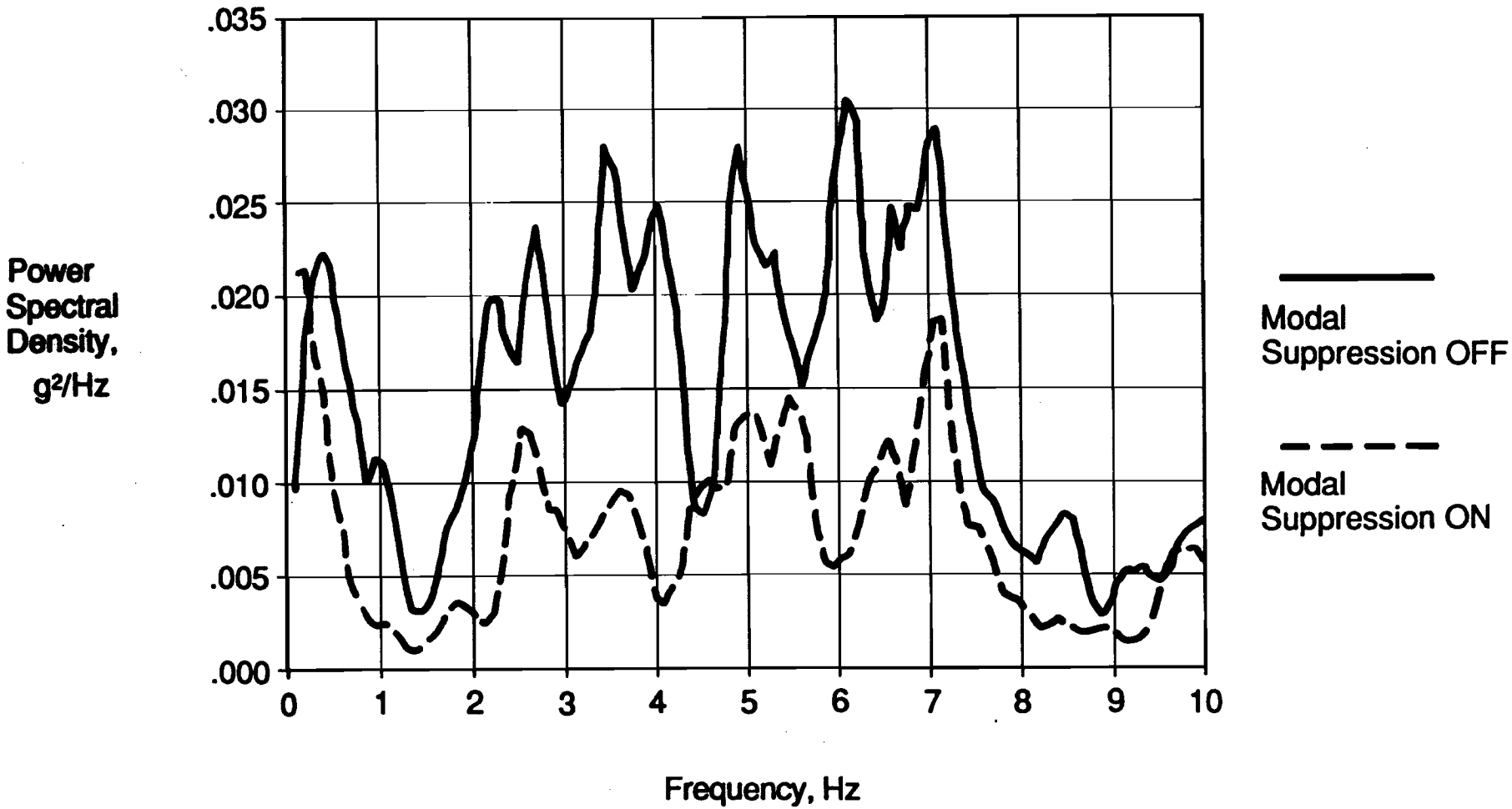
747-400
Power Spectrum
Vertical Acceleration - Right Wingtip



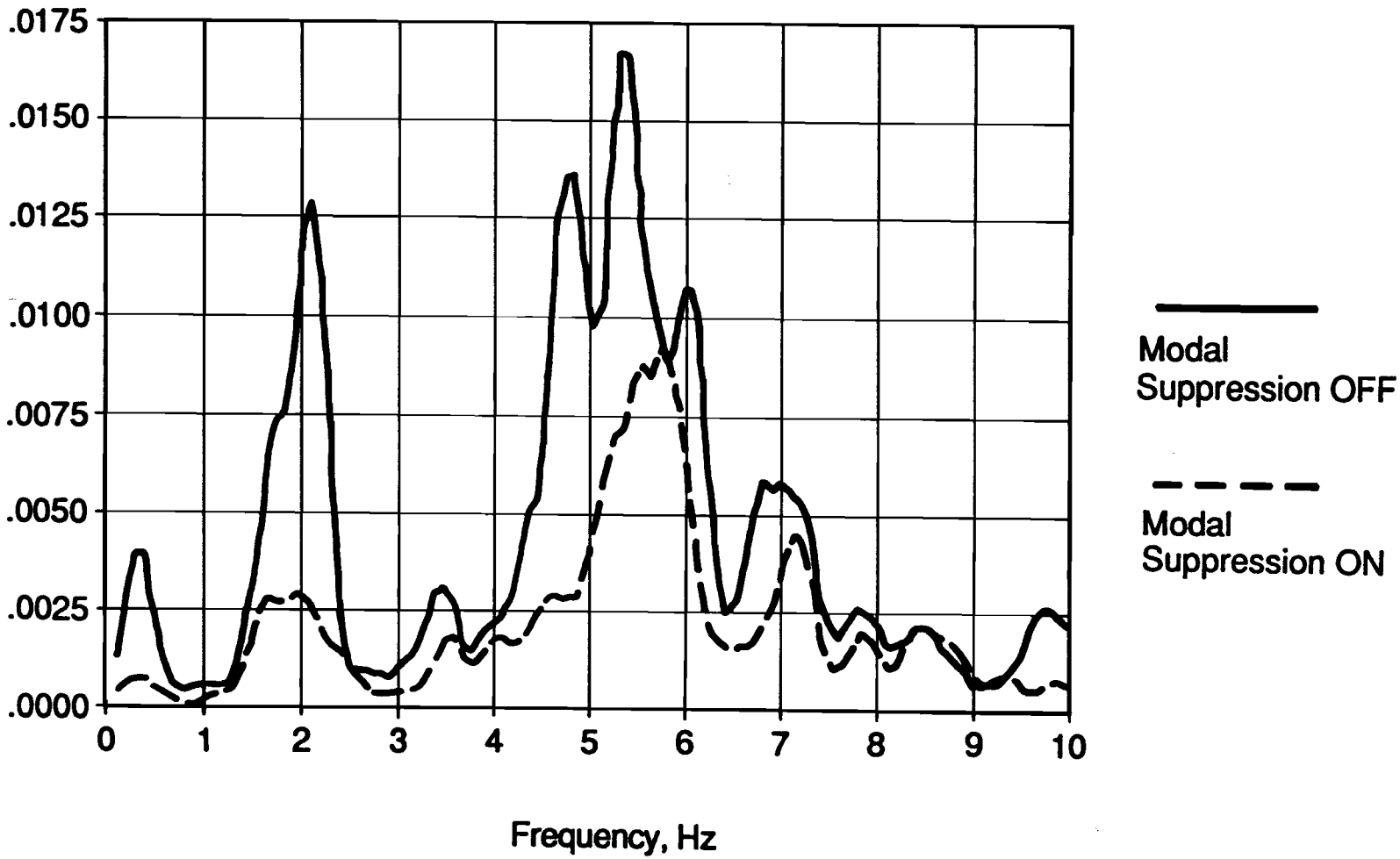
747-400
Power Spectrum
Vertical Acceleration - Left Wingtip



747-400
Power Spectrum
Lateral Acceleration - Fin Tip

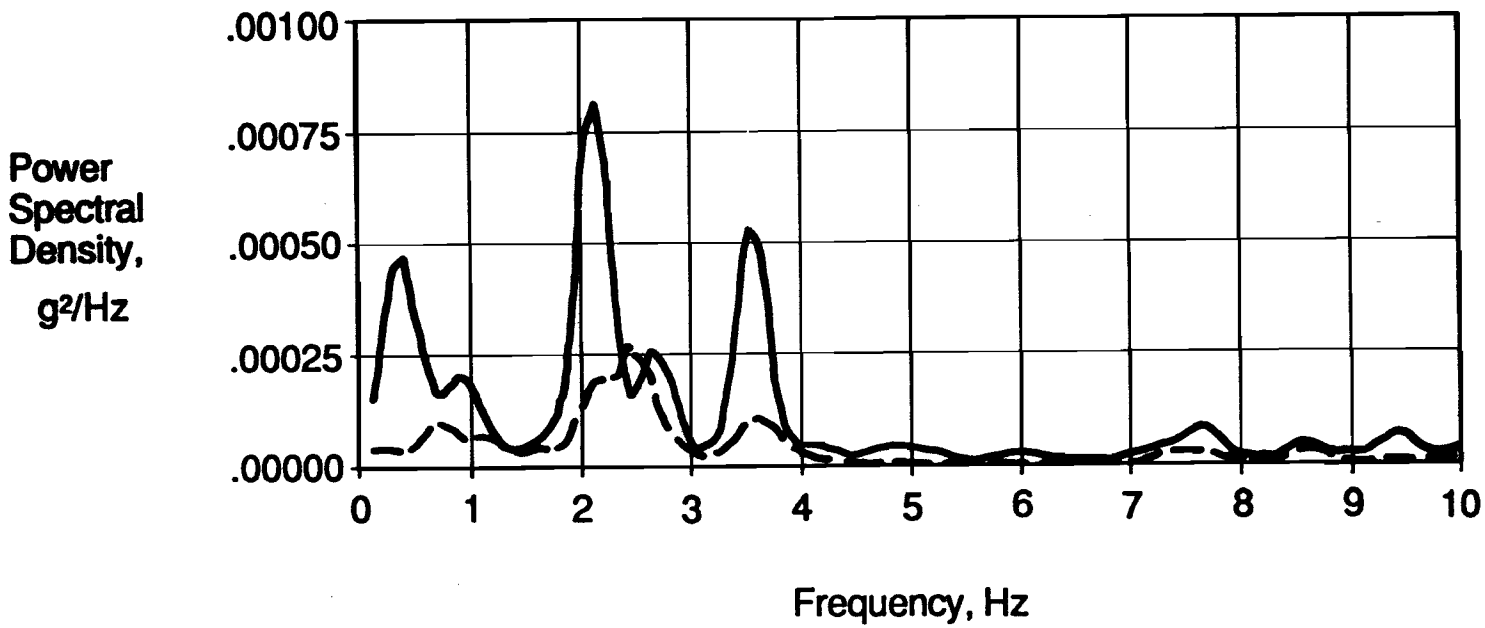


747-400
Power Spectrum
Vertical Acceleration - Left Stabilizer Tip



AAC-17

747-400
Power Spectrum
Lateral Acceleration at Pilots Seat

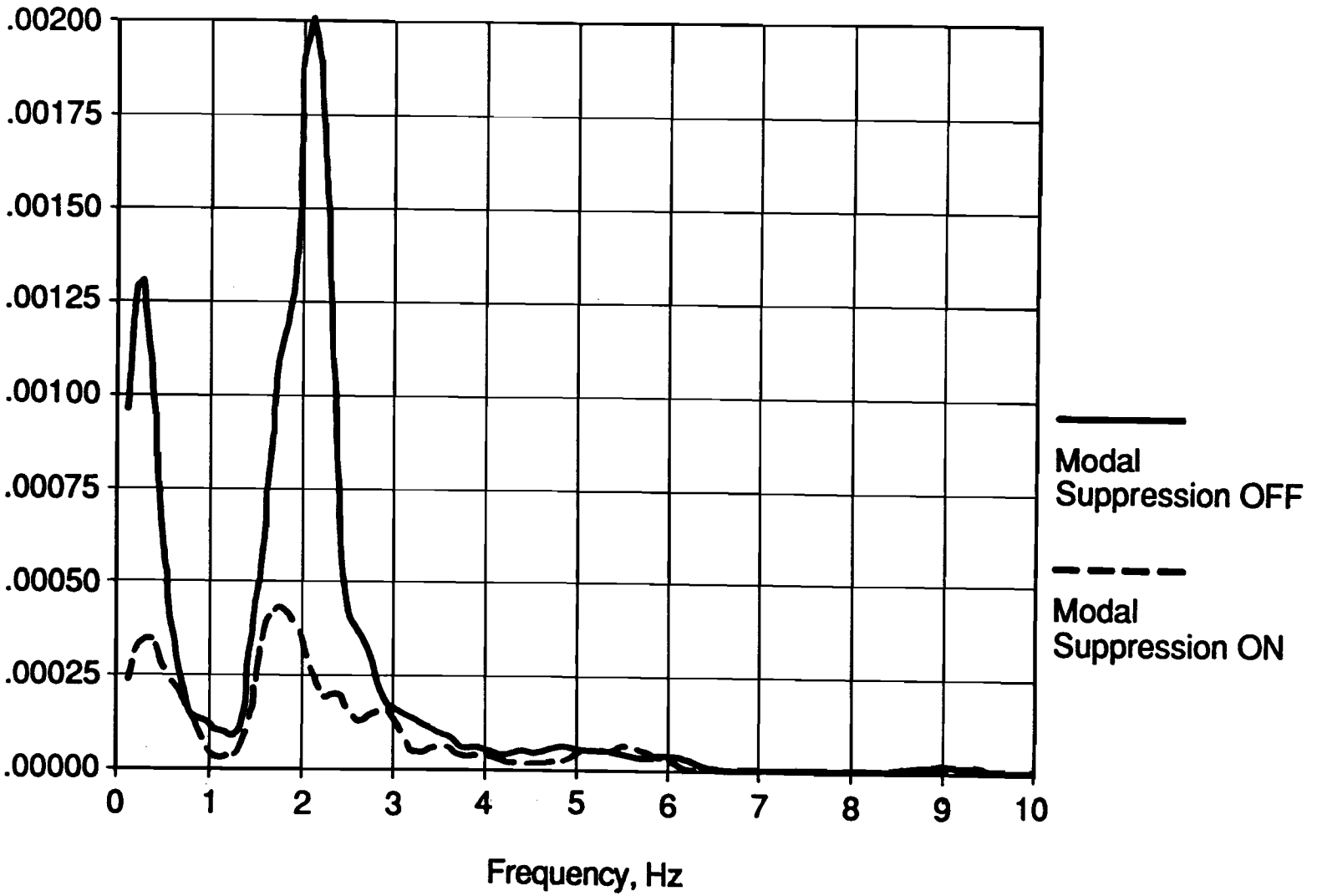


Modal Suppression OFF

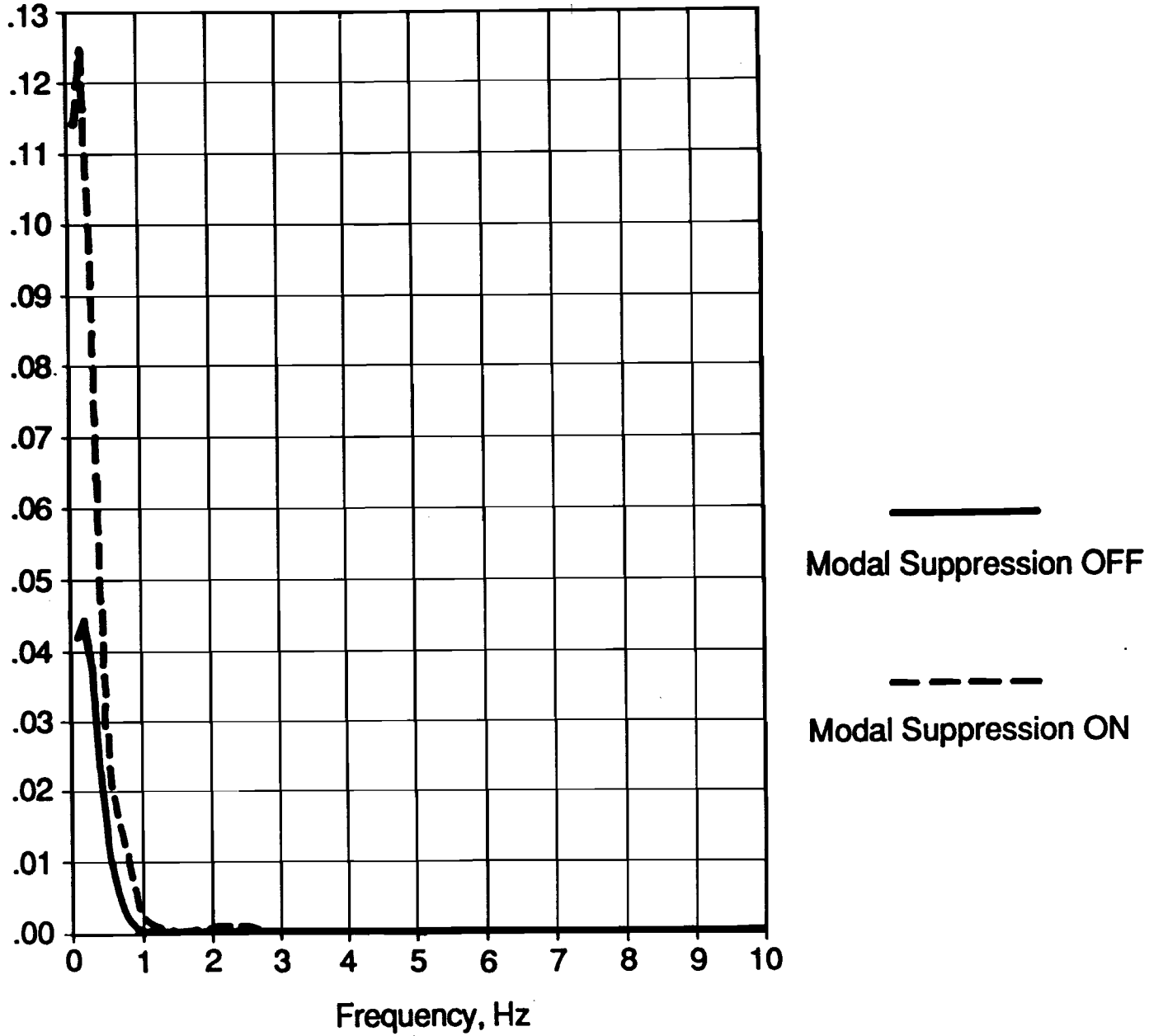
Modal Suppression ON

AAC-18

747-400
Power Spectrum
Lateral Acceleration at BS 2300

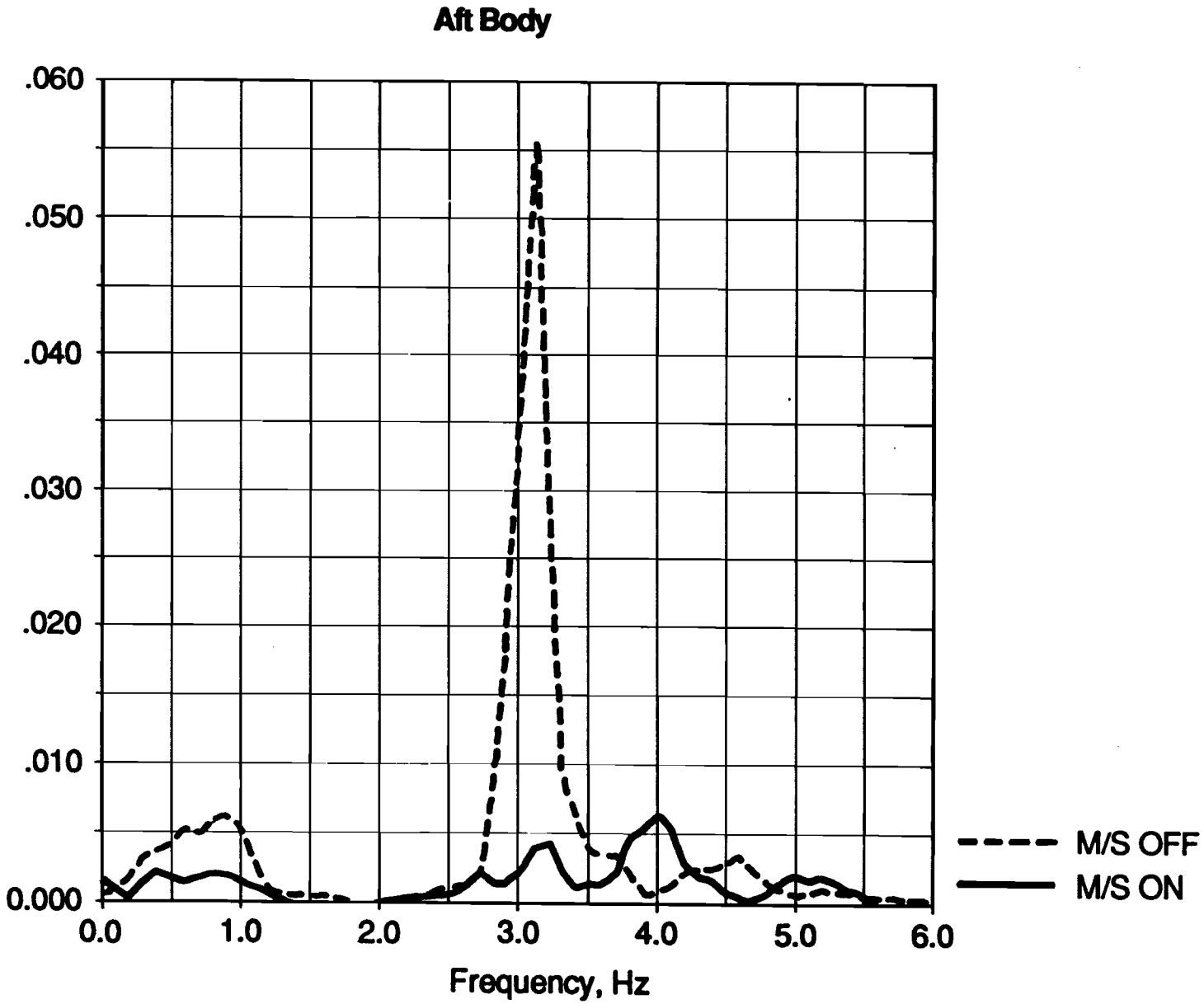


747-400
Power Spectrum
Rudder Position



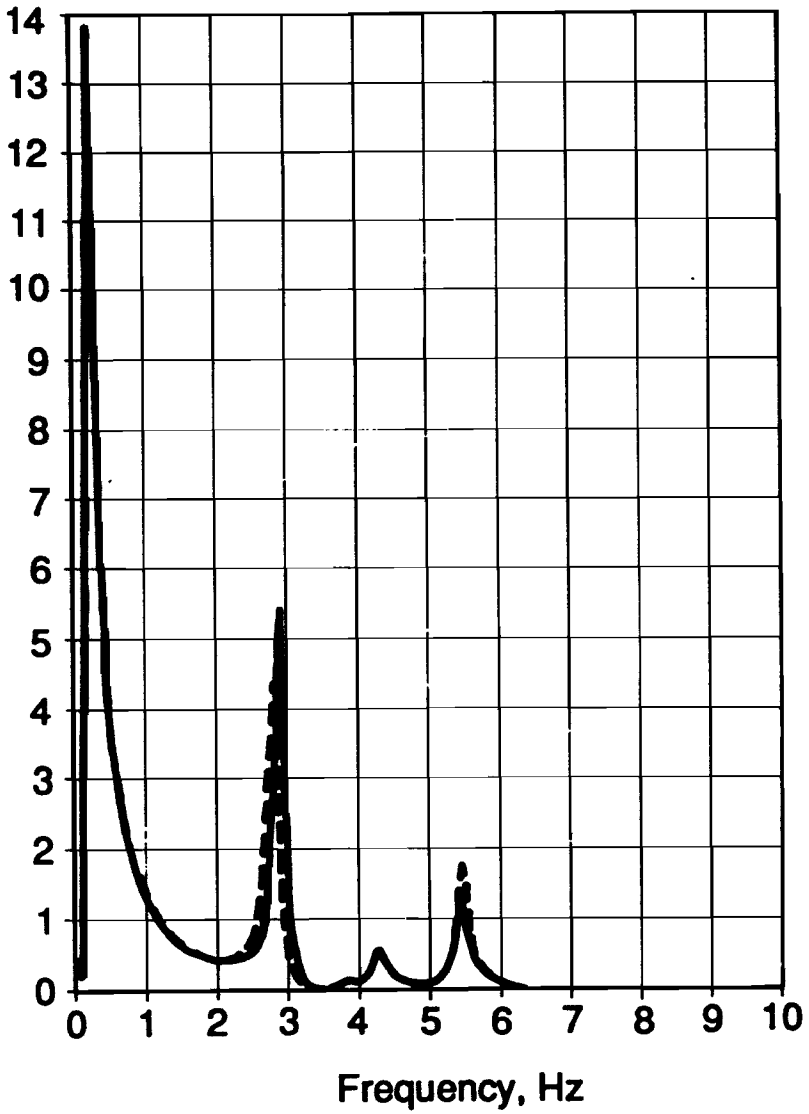
AAC-20

767-300
Modal Suppression Yaw Damper
15000 FT. MACH .60



AAC-21

767-300
Power Spectrum
Fuselage Lateral Bending Moment
Aft Pressure Bulkhead BS 1714



Modal Suppression OFF

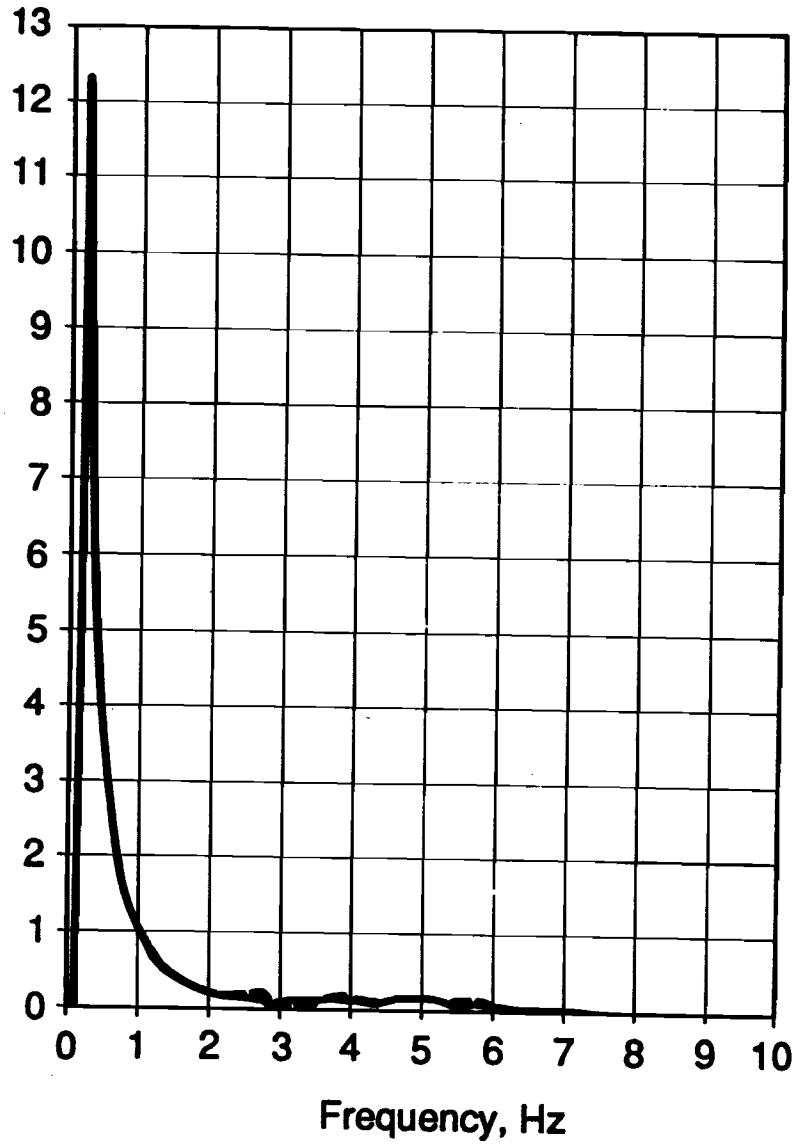
Modal Suppression ON

One Yaw Damper ON
in both cases *

* Minimum Dispatch Requirement

AAC-22

767-300
Lateral Gust Spectrum
Vertical Fin Root Bending Moment



Power Spectral Density,
1.0E16 (in-lb)²/rad/in

Modal Suppression OFF

Modal Suppression ON

One Yaw Damper ON
in both cases *

* Minimum Dispatch
Requirement

Summary Comments

- The major contributor to lateral ride discomfort is the dutch roll mode which accounts for about 60 percent of the acceleration in the aft body.

- Sideslip Rate is used to control dutch roll. In addition, a fast frame time microprocessor, 15 msec, is used together with a wide bandwidth servo, 70/(s+70). The original yaw damper system, without modal suppression, used a 51 msec frame time and a low bandwidth servoactuator, 35/(s+35). The frame time and servo change was made to allow better phase adjustment for the dutch roll and the flexible mode filters.

- There are two (2) structural modes of importance at the Aft Galley location: 1.75 and 2.0 Hz.

- There is one mode of importance at the Pilot's Station: 3.2 Hz.

- The Aft Body filter was designed first: The phase required was +40 degrees at 1.8 Hz. The total phase of the airplane plus controller was made equal to 0 degrees.

- The Fore Body filter was designed next: The phase was -278 degrees at 3.2 Hz. The total phase of airplane plus controller again was made equal to 0 degrees.

- The Aft Body and Vertical Tail root bending moments are not significantly affected by the Modal Suppression System; therefore, there is essentially no degradation in fatigue life.

Credits

Anissipour, A. A.; Benson, R. A.; Coleman, E. E.: *Modeling and Control Systems Design and Analysis Tools for Flexible Structures*

Anissipour, A. A.; Benson, R. A.: *Modifying High-Order Aeroelastic Math Model of a Jet Transport Using Maximum Likelihood Estimation*

Goslin, T. J.; Ho, J. K.: *Structural Stability Augmentation System Design Using BODEDIRECT: A Quick and Accurate Approach*

Ho, J. K.; Cooper, S. R.; Tran, C. B.; Chakravarty, A.: *On the Design of Robust Compensators for Airplane Modal Control*

Ho, J. K.; Goslin, T. J.; Tran, C. B.: *Aircraft Modal Suppression System: Existing Design Approach and its Shortcomings*

Tran, C. B.; Goslin, T. J.; Ho, J. K.; Chakravarty, A.: *Aircraft Fore and Aft Modal Suppression System*