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Final Report

GYRO NOISE MEASUREMENTS

Contract NAS 12-580

Report No. PPD-69-E-10268

9 October 1969

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Final Report

GYRO NOISE MEASUREMENTS

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Contract NAS 12-580

Report No. PPD-69-E-10288

9 October 1969

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SUMMARY

This report covers the results of noise measurements which were made on the two models of Northrop gyros, which are presently being considered for use in NASA's Tilt and Vibration Isolation System. Previous work has shown sensor noise to be one of the major limitations on the performance capability of an active stable pad.

From the results obtained, it can be concluded that the GI-V7 gyro is more suitable than the GI-T1-B gyro, from the noise standpoint, for this particular application. Although instrumentation/measurement problems due to test pad perturbations, instrument noise, etc., make it difficult to isolate gyro noise by itself, the relative values obtained make it obvious that the GI-V7-type gyro exhibits much less noise than the GI-T1-B-type gyro.

Figure VI in this report provides a comparison of the noise content of the two types of gyros plotted as Input Axis Displacement Power Spectrum vs. Frequency.

TEST DESCRIPTION

Figure I is a block diagram of the instrumentation used to measure the noise content of the gyros for frequencies above 10 Hz. Figure II is a block diagram of the instrumentation used to measure the noise content between 0.2 and 10 Hz. No measurements were made below 0.2 Hz because this was the minimum frequency setting on the Krohn-Hite Notch Filter. The frequency response of the Northrop designed Amplifier-Demodulator was checked after removing the output filter capacitors and replacing them with a 1 μfd capacitor. A Ling Servo Analyzer Model 401A was used and the Amp-Demod response was down 3 db at slightly over 500 Hz.

Figure III shows the frequency response obtained for the Keithley Null Detector (used as a DC amplifier). This amplifier was necessary to boost the level of the extremely low noise signal encountered when testing the GI-V7 type gyro. Due to the high frequency attenuation introduced by the Keithley, it was removed from the setup for measurements of frequencies over 10 Hz.

Figure IV shows the initial data obtained on a GI-T1-B gyro, S/N D840. The data was obtained using the instrumentation shown in figure I, and is restricted to values above 10 Hz because the frequency response of the RMS voltmeter is only good down to 10 Hz. The tests were conducted in Northrop's production test area. The gyro was mounted on a test pad attached to bedrock and no attempt was made to eliminate cultural noise or correct the data for instrumentation noise.

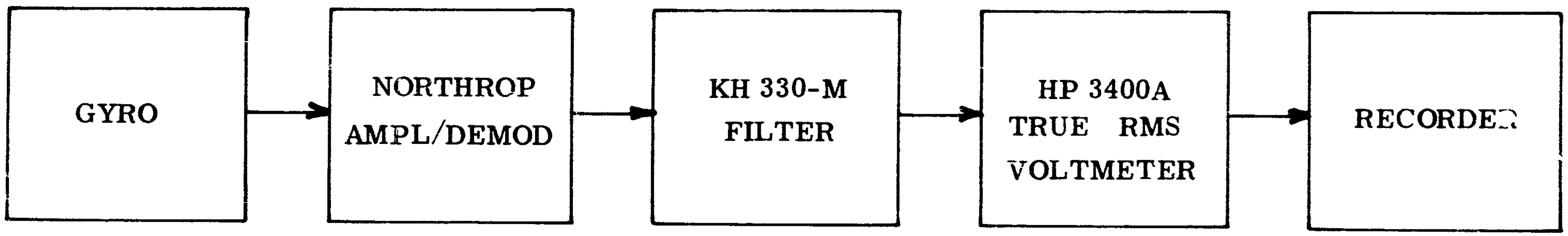


Fig. I Block Diagram - Instrumentation to Measure Noise Content of Gyros for Frequencies Above 10 Hz.

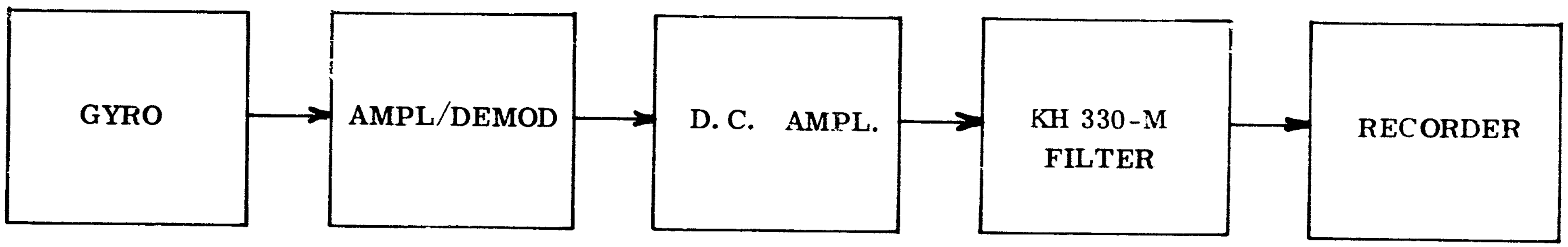


Fig. II Block Diagram - Instrumentation to Measure Noise Content of Gyros for Frequencies Between 0.2 Hz. and 10 Hz.

FIG. III KEITHLEY NULL DETECTOR -151R FREQUENCY RESPONSE

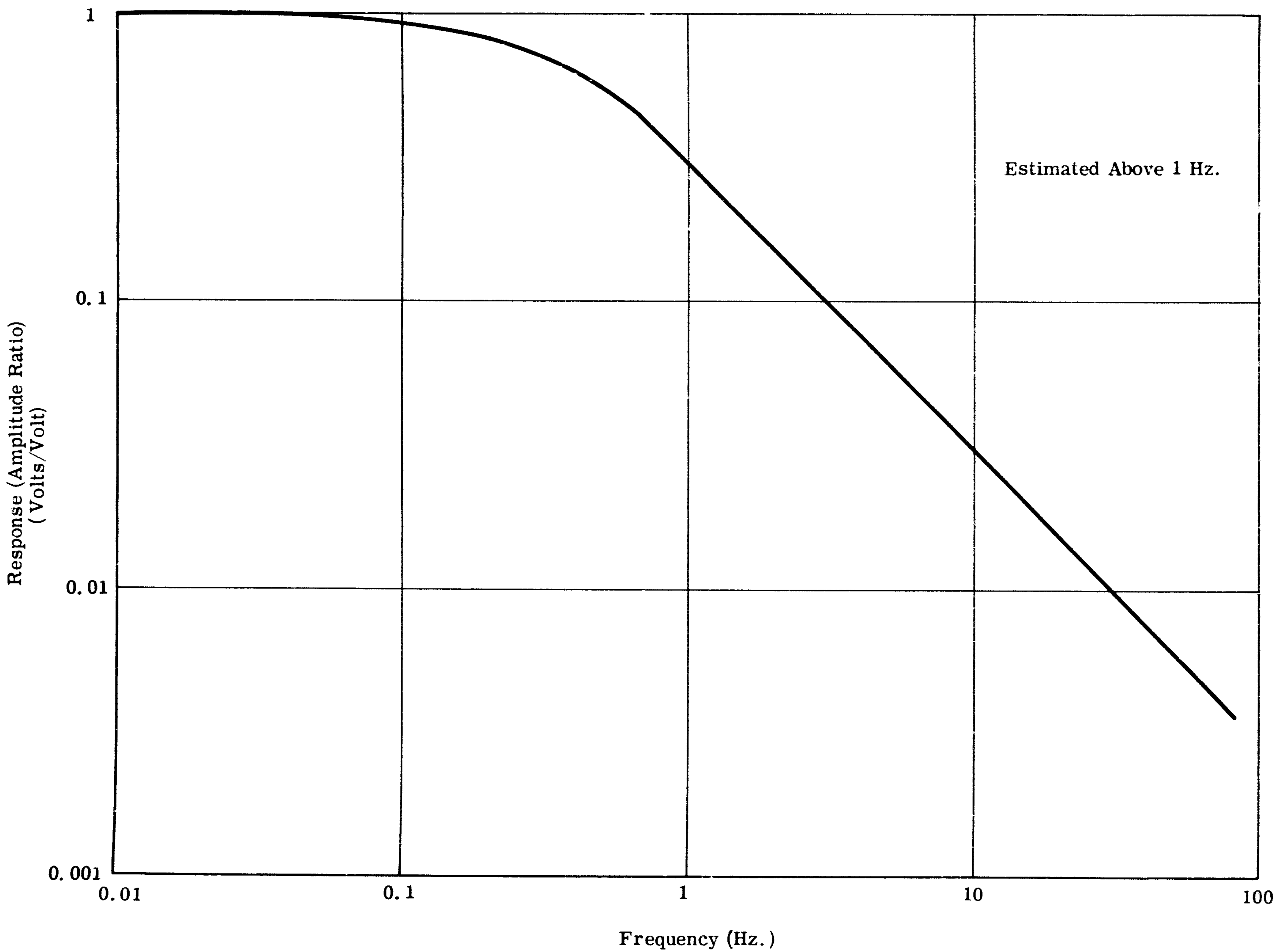


FIG. IV AVERAGE RMS GYRO NOISE
GI-T1-B-D840

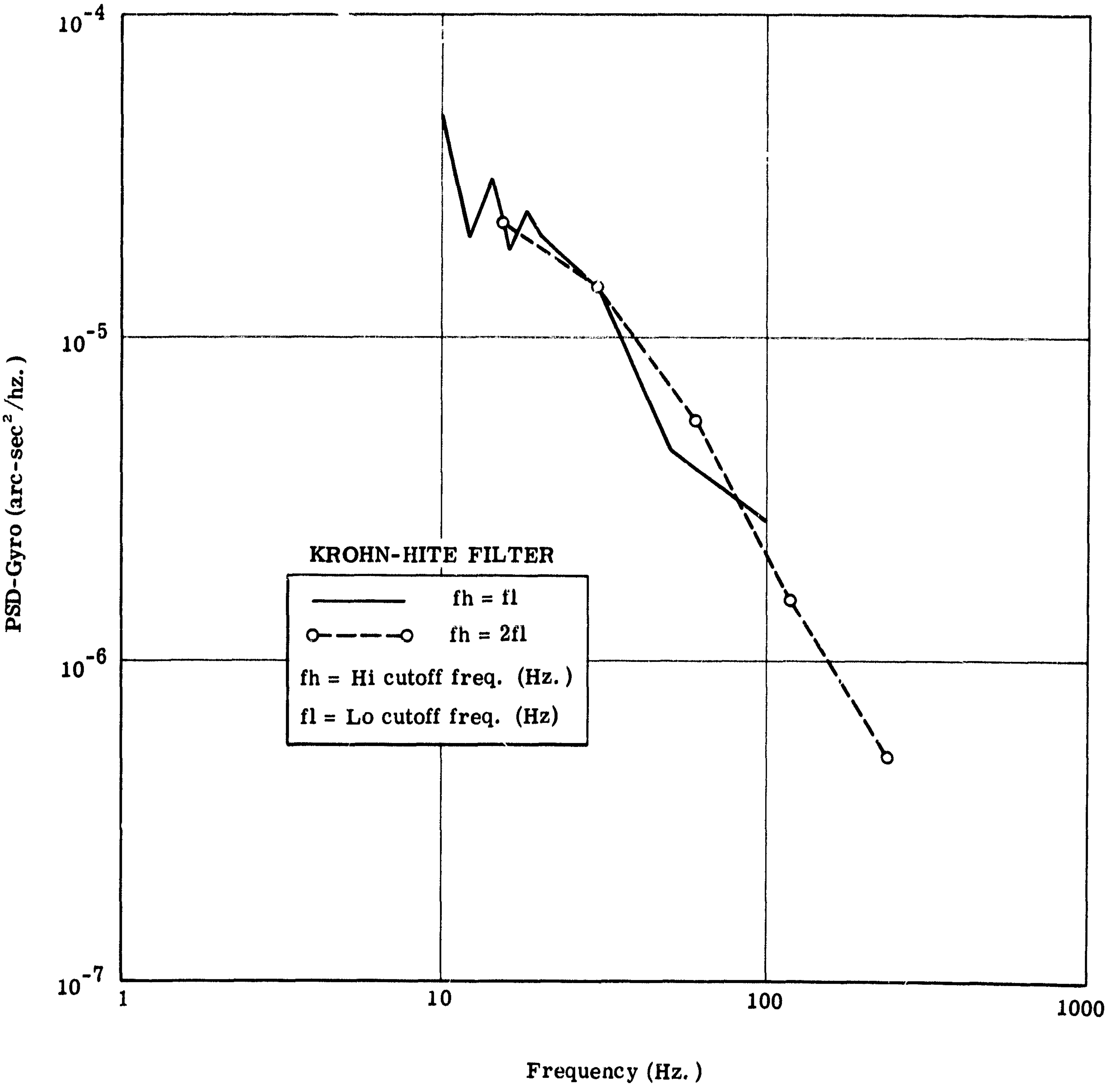


Figure V shows the frequency response of the GI-V7 gyro, calculated as a two-degree-of-freedom gyro and measured as reported in Northrop's Report No. PPD-68-E-10245, "Evaluation Report, Tilt and Vibration Isolation System". The calculated response used the following GI-V7 parameters:

$$I_x = 2.15 \times 10^4 \text{ gm-cm.}^2$$

$$I_y = 1.5 \times 10^4$$

$$K_x = 7.5 \times 10^8 \text{ dyne-cm./rad.}$$

$$K_y = 7.55 \times 10^3$$

$$H = 9.2 \times 10^6 \text{ dyne-cm.-sec./rad.}$$

$$C_x = 3 \times 10^8 \text{ dyne-cm.-sec.}$$

$$C_y = 5.9 \times 10^4$$

Figure VI is a plot of the results obtained from testing both a GI-V7 and a GI-T1-B gyro. It shows relative noise values between 0.2 and 200 Hz for the two gyros obtained from the instrumentation shown in figures I and II. The data has been plotted as input axis displacement power spectral density (arc-sec.^{2}/Hz) vs. frequency. Below 10 Hz, average peak-to-peak values were used as representative of the data obtained. Above 10 Hz, average RMS values were used.

Before plotting the data for figure VI, the instrumentation noise was removed. To do this, two measurements were made. The first measurement was made with the gyro signal generator being fed into the amplifier-demodulator input. The second measurement was made with the input terminal of the amplifier-demodulator shorted to ground. With the input shorted, the signal recorded

FIG. V GI-V7 RESPONSE CALIBRATION CURVE

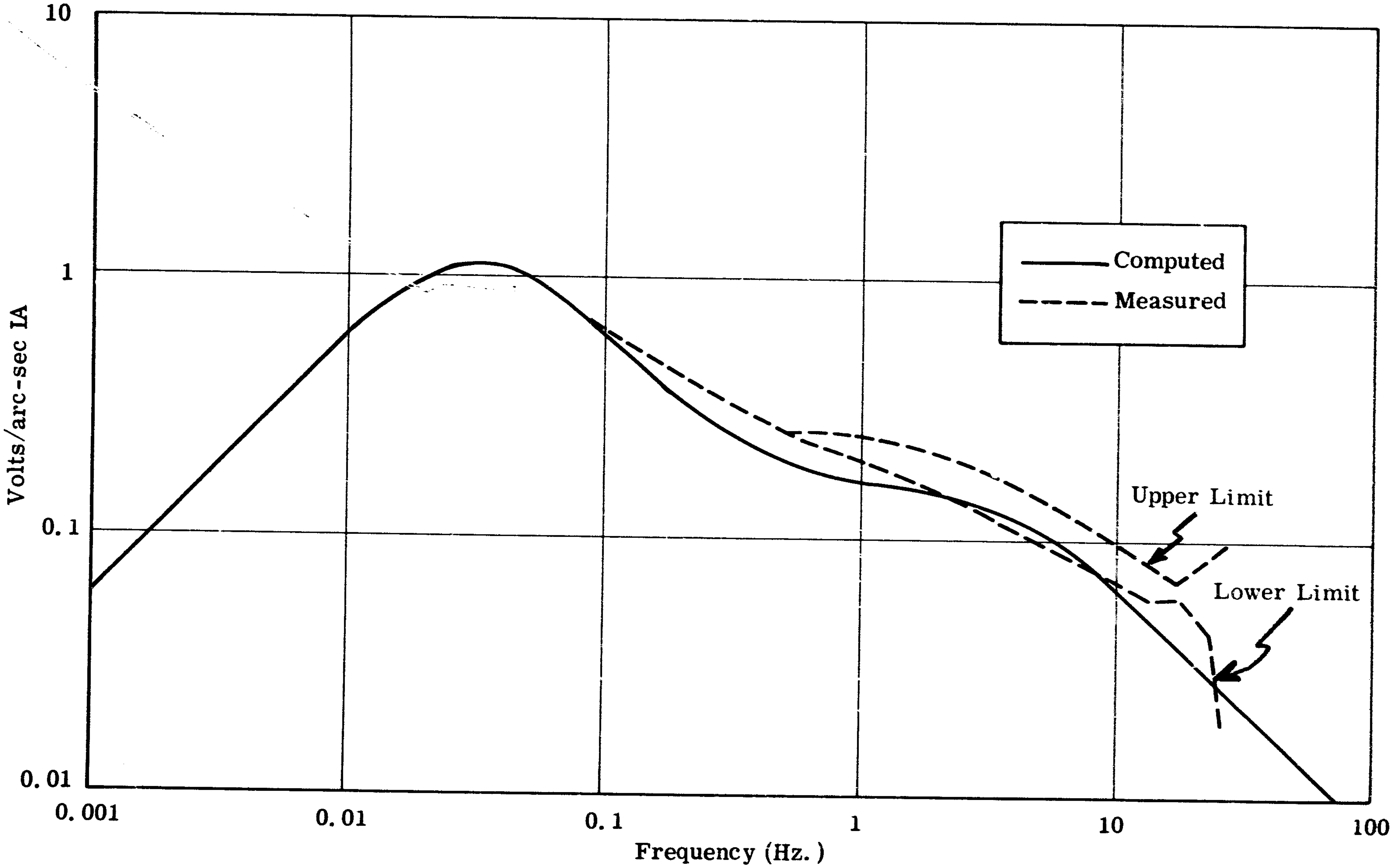
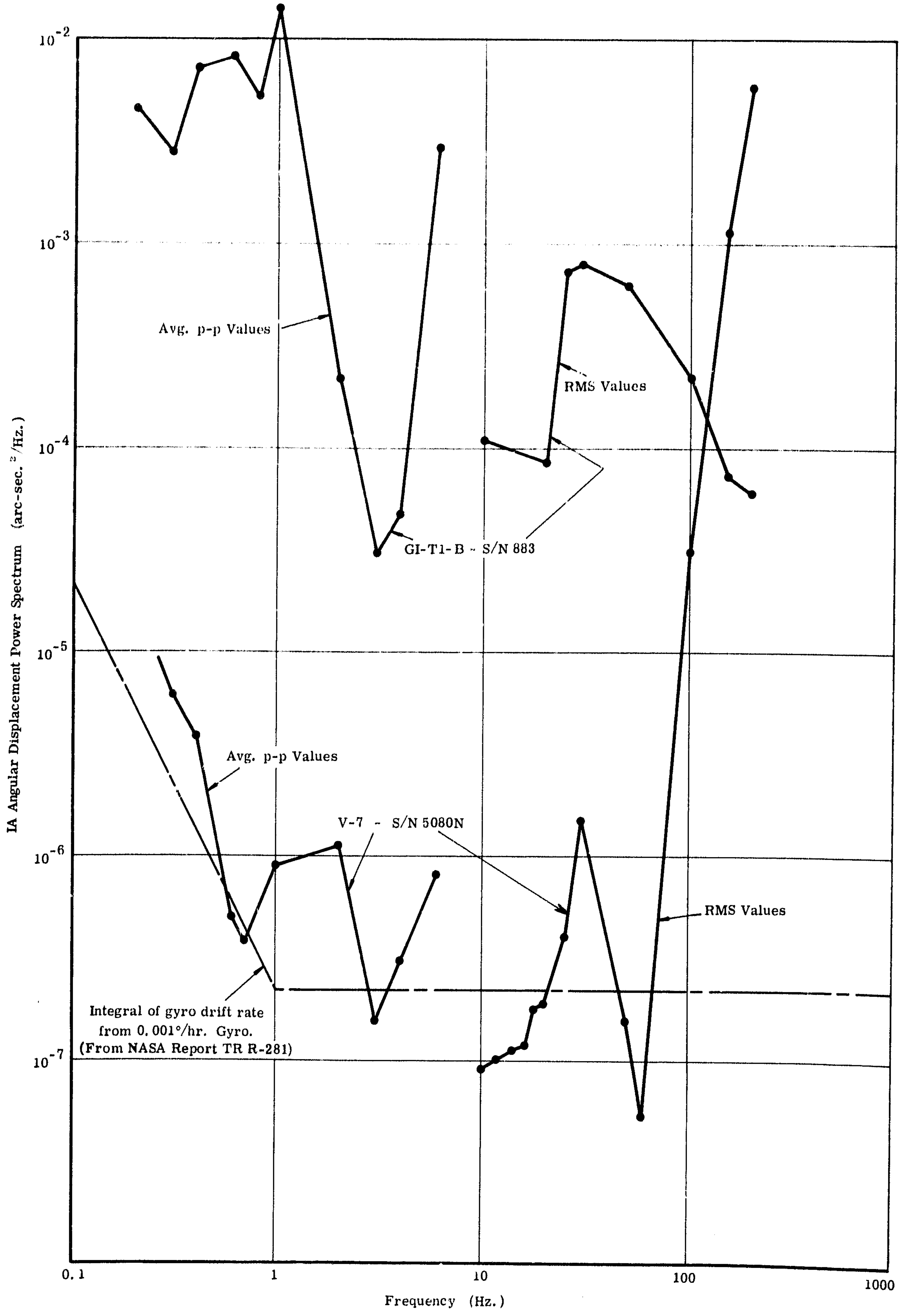


FIG. VI EQUIVALENT INPUT AXIS ANGULAR DISPLACEMENT POWER SPECTRUM FOR GYRO NOISE



was assumed to be the noise generated in the test setup. The difference between the two readings was then assumed to be the noise content of the gyro signal generator. Appendix A shows a sample of the data reduction method used.

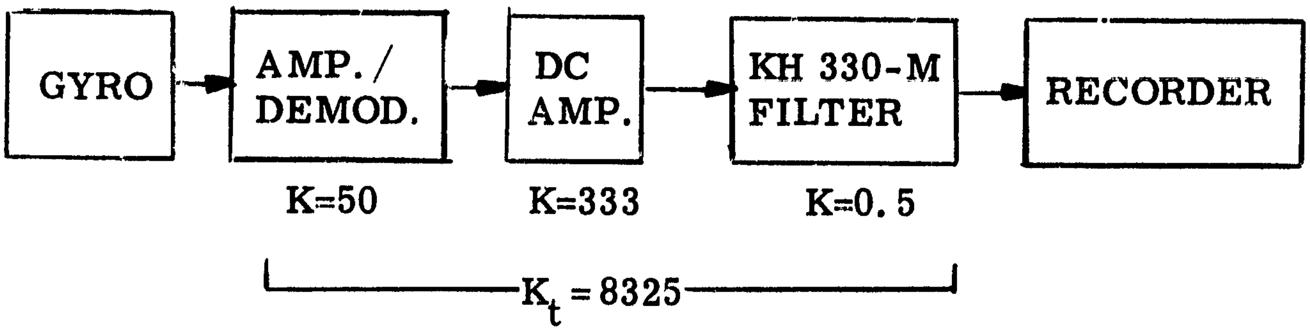
These values still contain any cultural noise associated with the time and location of the measurements. The tests on the GI-T1-B were made in Northrop's Production Test Area, while the tests on the GI-V7 were run in Northrop's Ultra Precision Test Laboratory. The test pads in both areas are built on the same bedrock so the cultural noise should be approximately the same for each.

APPENDIX A
NOISE DATA REDUCTION

Figure A-1 is a sample of the low frequency data taken with the instrumentation shown in block diagram form in figure II of this report and reproduced below. The data as read from the recording was divided by the over-all gain to determine the equivalent noise input in arc-seconds about the IA.

The gain of the amplifier-demodulator was 50. The dc amplifier gain was 333. The filter for all the narrow-band measurements has a gain of 0.5. Narrow band measurements were made to permit the data to be representative when plotted as PSD vs. frequency. The RMS voltmeter has a gain that varied during these tests from 33 to 1000 depending on the scale used. This over-all gain was then multiplied by a factor, to account for the frequency response of the gyro and the dc amplifier, before it was divided into the recorded data.

From figure A-1, the output noise (avg.) equals 4.75 mv. The noise with the input to the amplifier/demodulator shorted equals 2.625 mv. The instrumentation gain is



Multiply by gyro gain of 1.79 at 0.8 Hz and dc amplifier factor of 0.38 and the over-all gain is 5663. (Adjusted gain = 8325 x 1.79 x 0.38 = 5663.)

$$\frac{4.75 - 2.6}{5663} = 0.0004 \text{ arc-sec. avg. p-p noise about the input axis}$$

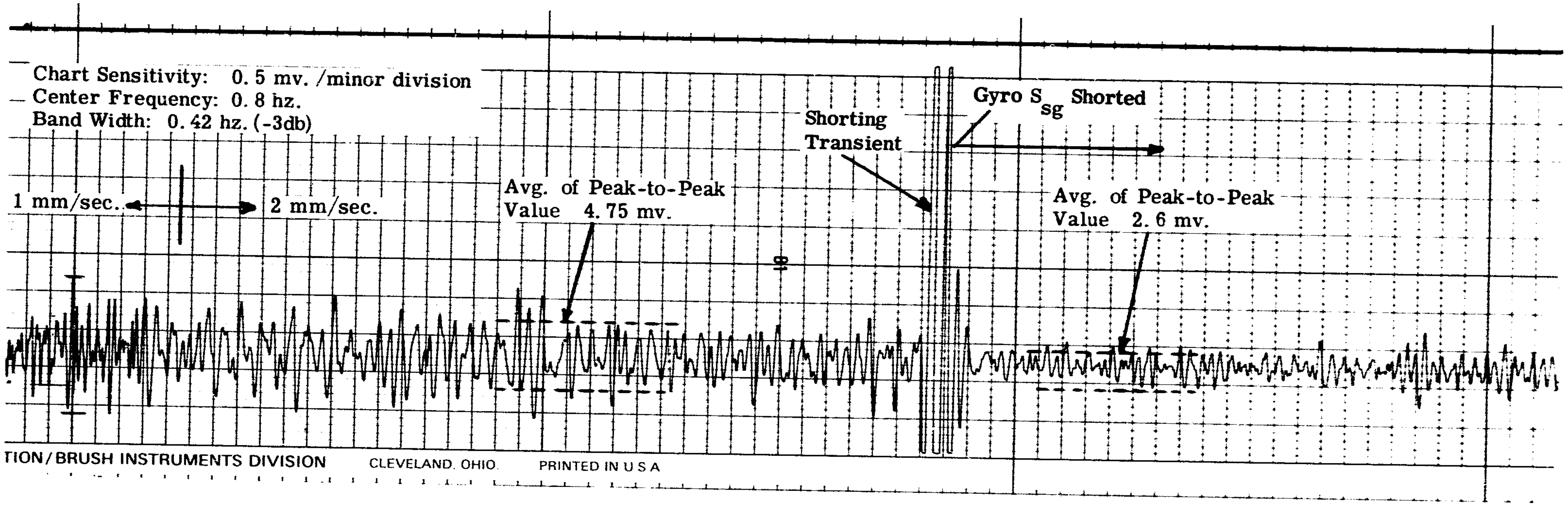


FIGURE A-1 TYPICAL NOISE OUTPUT OF GI-V7 GYRO

The bandwidth of the filter is from 0.77 to 1.3 of the set frequency when the low-frequency and high-frequency cutoffs are set for the same value. The PSD is therefore

$$PSD = \frac{(0.0004)^2}{BW} = \frac{0.16\ (10^{-6})}{0.42} = 3.81 \times 10^{-7}\ \text{arc-sec.}^2/\text{Hz}$$