FINAL REPORT

FLIGHT OFF-LOADING QUAL CONFIDENCE PROGRAM FOR ARRAY A ALSEP SUBPACKAGE 2

Submitted as the Completion of the
Report Requirements of ALSEP CCP-98

Prepared by: J. Maszatics
J. Maszatics

Prepared by: J Brueger
J. Brueger

Approved by: M. Katz
M. Katz

CONTENTS

1.0 SUMMARY

A series of tests were conducted in order to determine the effects of off-loading (removing), either the SIDE or the ALHT from the ALSEP subpackage 2, upon the dynamic environment of the remaining subsystems.

The test results indicate that dynamic levels of the remaining subsystems will be substantially increased if either experiment is off-loaded. Consequently, off-loading experiments on ALSEP subpackage 2 cannot be recommended, unless qualification tests are conducted to verify that the off-load environment does not damage the hardware.

If such qualification tests are not feasible and the risk of "flying" unproven equipment is considered acceptable, then it is recommended that the ALHT be off-loaded. The test data from subpackage #1 and #2 off-loading tests indicate that the ALHT-removed-configuration is the minimum risk configuration.

2.0 INTRODUCTION

2.1 PROGRAM REQUIREMENTS

In a TWX (reference 6.1) from NASA Houston Bendix was directed to design, instrument and conduct engineering vibration tests on "experiment off-loaded" configurations of ALSEP Subpackages 1 and 2. The test program was "to provide confidence in the prior qualification and acceptance testing of the four-experiment ALSEP configuration."

The experiment off-loaded configurations of ALSEP Subpackage 2 were defined in the NASA TWX (reference 6.1) as follows:

(Baseline)	RTG, SIDE, ALHT
	RTG, SIDE
	RTG, ALHT

These equipments are defined as follows:

RTG — Radioisotope-fueled Thermoelectric Generator

SIDE — Suprathermal Ion Detector Experiment

ALHT — Apollo Lunar Hand Tools

Test article instrumentation was to be similar to the Proto A vibration tests. Sufficient tests were to be conducted to provide "single data point correlation between off-loaded configurations and four-experiment configurations previously tested." No functional tests of ALSEP System equipment were to be made as part of these tests.

The equipment to be used in the Subpackage 2 assembly was defined in reference 6.1. The identified equipment included the D-2 (LM-3) Subpackage 2 structure which was not completed and therefore not available. The Qual A subpackage 2 structure was available, was modified, and used as a substitute. The other equipment identified in reference 6.1 for subpackage 2, was used as specified.

The NASA TWX called for the test completion by 7 May 1968 and final report submittal by 15 June 1968. It also specified that no ALSEP schedule impacts were to be associated with this program. Although the Subpackage 1 tests were completed prior to the specified date, the ALSEP schedule did not permit the build-up and test of Subpackage 2 until 11 July, 1968. In addition, delays in the availability of reduced data and support personnel, as a result of other ALSEP commitments, did not permit completion of this report until the present time.

2.2 ALSEP Experiment Off-Loading

The reasons for employing an off-loaded ALSEP in a lunar landing mission would be due to either a subsystem failure prior to launch or an intolerable overweight situation. In the event that a defective subsystem is identified during pre-launch operations, a decision may be made to remove it and transport ALSEP to the lunar surface in an off-loaded configuration. If the final weight of ALSEP is identified as unacceptable for flight, a decision would undoubtedly be made remove weight in the form of one of the subsystems.

The most immediate effect to off-loading is to change the ALSEP Subpackage 2 total weight and center-of-gravity location. Table 2-1 summarizes the present calculated weight and c.g. location of the Subpackage 2. (Qual SA and Flights 1 & 2) It also shows the calculated weight and c.g. location for each of the off-load configurations defined for these tests in reference 6.1.

Another effect of off-loading is to change the mass distribution on the primary pallet. This test program is intended to provide data on the effects of such mass removal, in the form of subsystem removal, on the vibrational inputs to the remaining subsystems.

2.3 PROGRAM IMPLEMENTATION

The test requirements were identified in References 6.2 and 6.3, including the hardware to be assembled for Subpackage No. 2.

The Qual A primary pallet had already been reworked to the Qual SA configuration prior to the off-load program to permit its use on the Qual SA assembly for the Acceptance 2 tests. The Qual A subpallet, however, was also required to be reworked for use in the off-load assembly of Subpackage 2. The rework consisted of the addition of 3 inserts in the honeycomb structure and the addition of a pad under one of the inserts. The subpallet was returned from the vendor and available for assembly buildup on 12 June 1968. Assembly was not completed until 11 July, 1968. Support of the ALSEP manufacturing schedule prohibited earlier assembly of this subpackage.

The primary pallet has been identified for subsequent use in the build up of the Proto B Subpackage 2. Its diversion to the off-load program did result in some impact on the Proto B schedule.

TABLE 2-1

MASS PROPERTIES EFFECTS EXPERIMENT OFF-LOADING SUBPACKAGE 2

	Present Configuration		Off-Load Configurations	
	Qual SA	Flights 1 & 2	With RTG, SIDE	With RTG, ALHT
Weight	100.9	98.8	80.9	77.6
$\overline{X}_A$	9.3	9.3	8.0	8.8
$\overline{Y}_A$	12.9	12.9	12.8	15.7
$\overline{Z}_A$	11.45	11.45	13.4	10.1
Δ_S				
Spherical Radius from Specification center of gravity. (Tolerance = 5.0)	1.84	1.84	3.40	4.34

The tests were run on 16-18 July, 1968, the earliest test facility availability after hardware buildup. Reduced data was made available on 18 Oct. 1968 and analysis was completed on 22 Nov. 1968.

This report together with references 6.17 and 6.18 completes the report requirements of ALSEP CCP-98.

3.0 TEST DESCRIPTION

3.1 TEST ARTICLE

The engineering off-loading vibration tests were performed on the ALSEP Array A Subpackage 2 configuration. This configuration was assembled from the following basic ALSEP parts:

Part Name		Dwg. No.
Primary Pallet	Qual A S/N 2	2338200 (as reworked for Qual SA Acceptance #2 vibration tests)
Subpallet Assy	Qual A S/N 2	2334290 (as reworked to provide inserts and pad per 2333270 G, to remove tool support and to remove tool insert per 2338561)
RTG	Mechanical Model Proto A	47R300839G1 GE SN/M-5 6283101
RTG Cable Reel Assy.	Proto A	2330268A 2334282A SN-2
Shorting Plug Assy.	Proto A	2331586

Part Name		Dwg. No.
ALHT	Mass Simulator	SDB39101556-102 S/N 101
SIDE	Dummy Proto A	No Part No.
Antenna Gimbal Box	Proto A	2333303
Antenna Aiming Mechanism	Proto A	2330309 SN/2
Simulated Fwd Tool Support and Ballast	As used in Qual SA Acceptance #1 Vibration Test	BSX 7664
Center Ballast - Tool Simulation		BSX 7665
Rear Ballast - Tool Simulation		BSX 7666

Calfax Live-lock fasteners were used in the primary pallet and sub-pallet and to tie down the experiment and other equipment. These fasteners were lock-wired where permitted by their locations.

Assembly of Subpackage 2 was completed and the subpackage was delivered to the test facility on 11 July, 1968.

3.2 Test Configuration

The specific configurations tested were as defined in reference 6.1. These configurations are obtained by the removal of the SIDE or the ALHT from the basic ALSEP Array A Subpackage 2 configuration. The configurations were designated, for identification purposes, as follows:

Configuration α_2: RTG, SIDE, ALHT

Configuration β_2: RTG, SIDE

Configuration γ_2: RTG, ALHT

In removing a subsystem only the subsystem and the associated fastener studs were removed; the unused support brackets and fastener receptacles were left on the test article.

3.3 Test Environment

Configuration α_2, β_2, and γ_2 of ALSEP Subpackage 2 were vibrated in each of the three ALSEP axes, as defined in figure 3-1, at the present sinusoidal and random qualification levels. The qualification levels used are shown in figures 3-2, 3-3, 3-4 and 3-5 and are from reference 6.11 for the launch and boost phases of the lunar flight.

The sinusoidal environment was run from 5 Hz to 100 Hz at a sweep rate of 3/4 octave per minute. The random vibration environments were run for a duration sufficient to obtain a 10 second loop of recorded data from all accelerometers, which required a duration of about 30 seconds in each axis for each configuration.

3.4 Test Instrumentation

Accelerometers were mounted on the test article to provide data on the vibration input to the experiment and equipment mounted on the test article. The accelerometers were mounted at the locations shown in Figure 3-6. The triaxial accelerometers for the RTG input were mounted on the primary pallet near the pallet interface with the RTG. The single axis and triaxial accelerometers for the SIDE, Antenna Gimbal Box and ALHT were mounted on the sub-pallet or, for the SIDE, on the appropriate support bracket.

In addition a control accelerometer was mounted on the vibration test fixture to which the ALSEP subpackage was mounted.

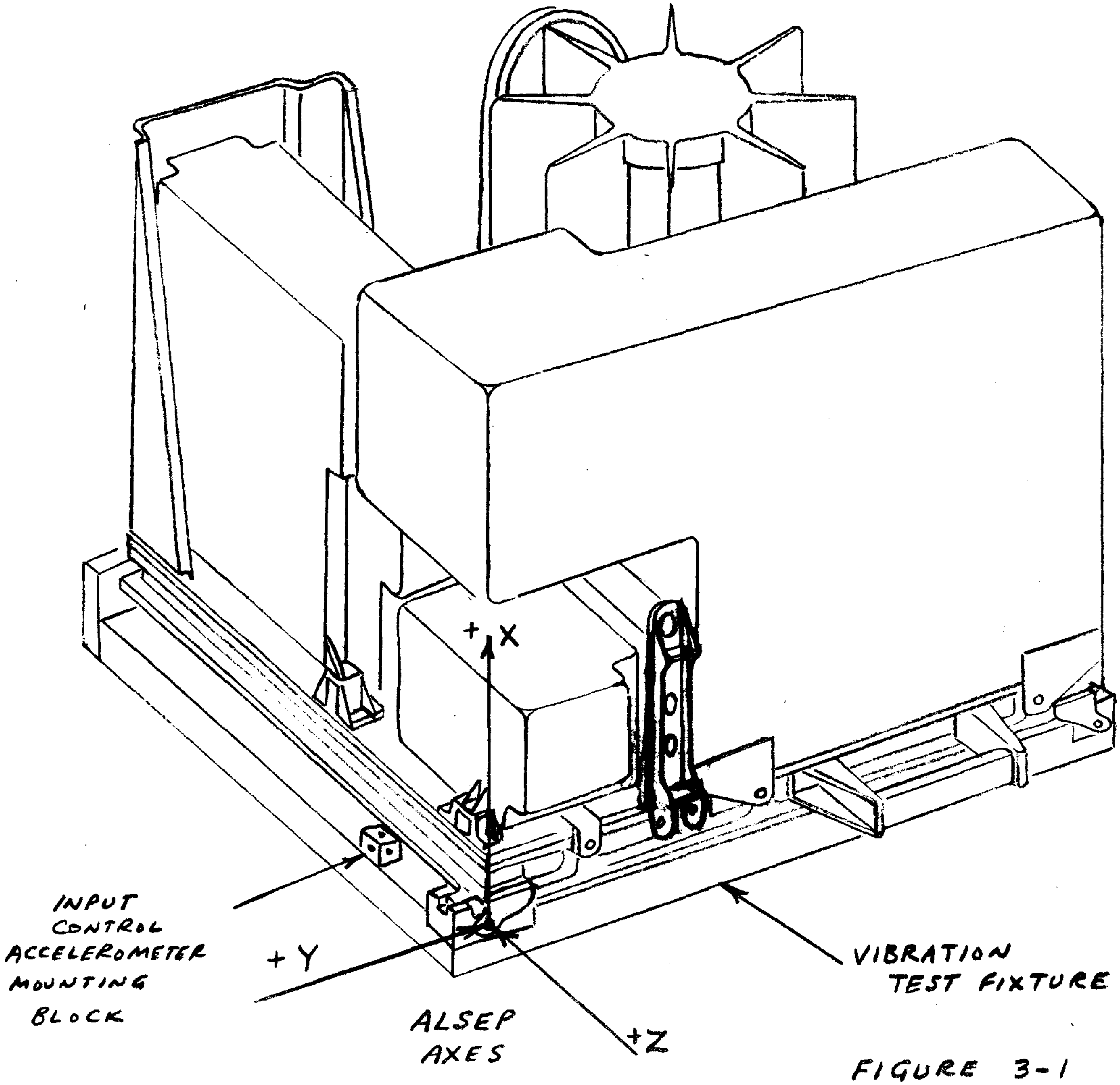


FIGURE 3-1
IDENTIFICATION OF ALSEP AXES
SUBPACKAGE 2

FIGURE 3-2

SINUSOIDAL VIBRATION

X, Y, Z -AXES

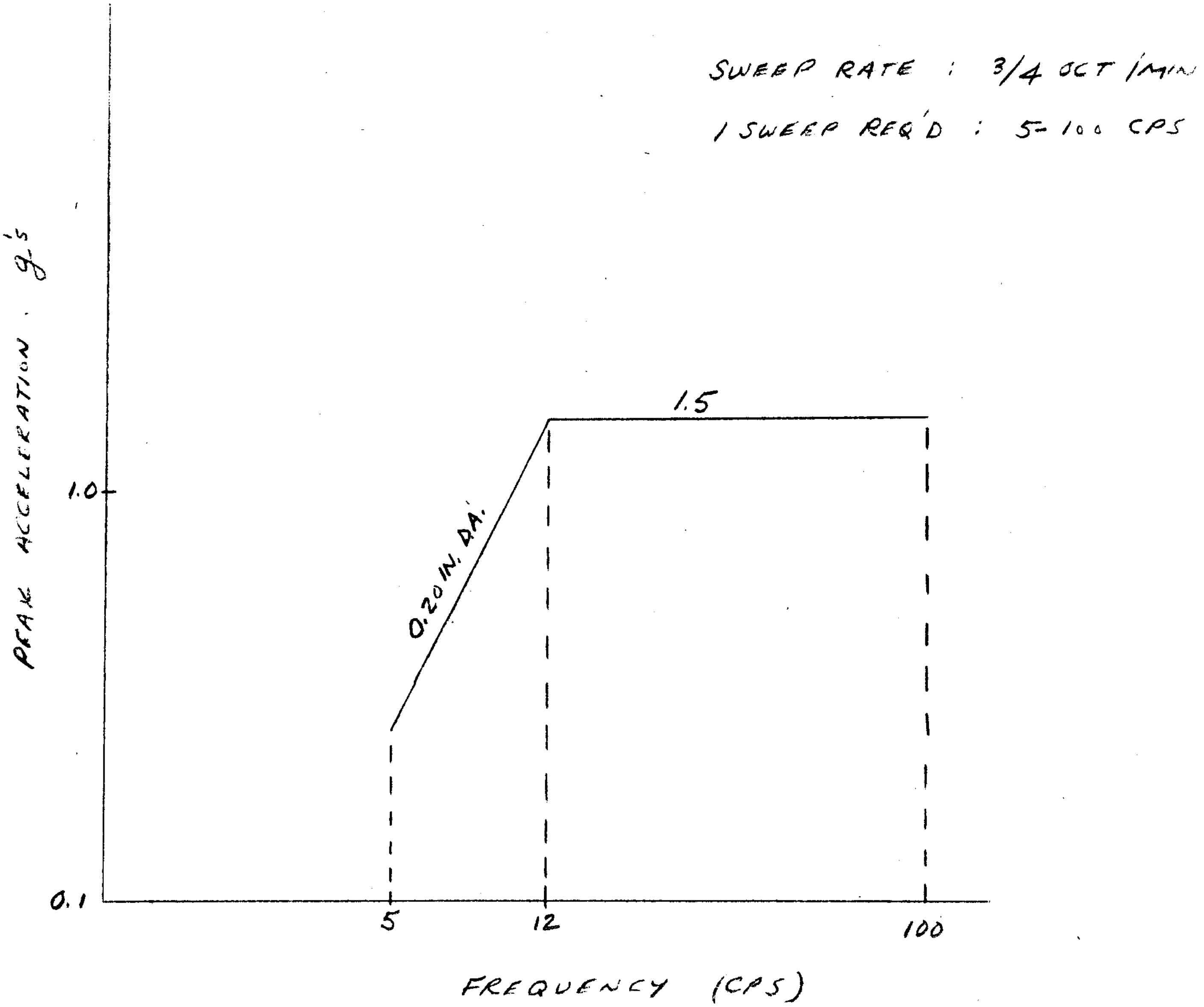


FIGURE 3-3
RANDOM VIBRATION
X - AXIS

DURATION: AS REQ'D TO
OBTAIN 10 SEC
TAPE LOOP

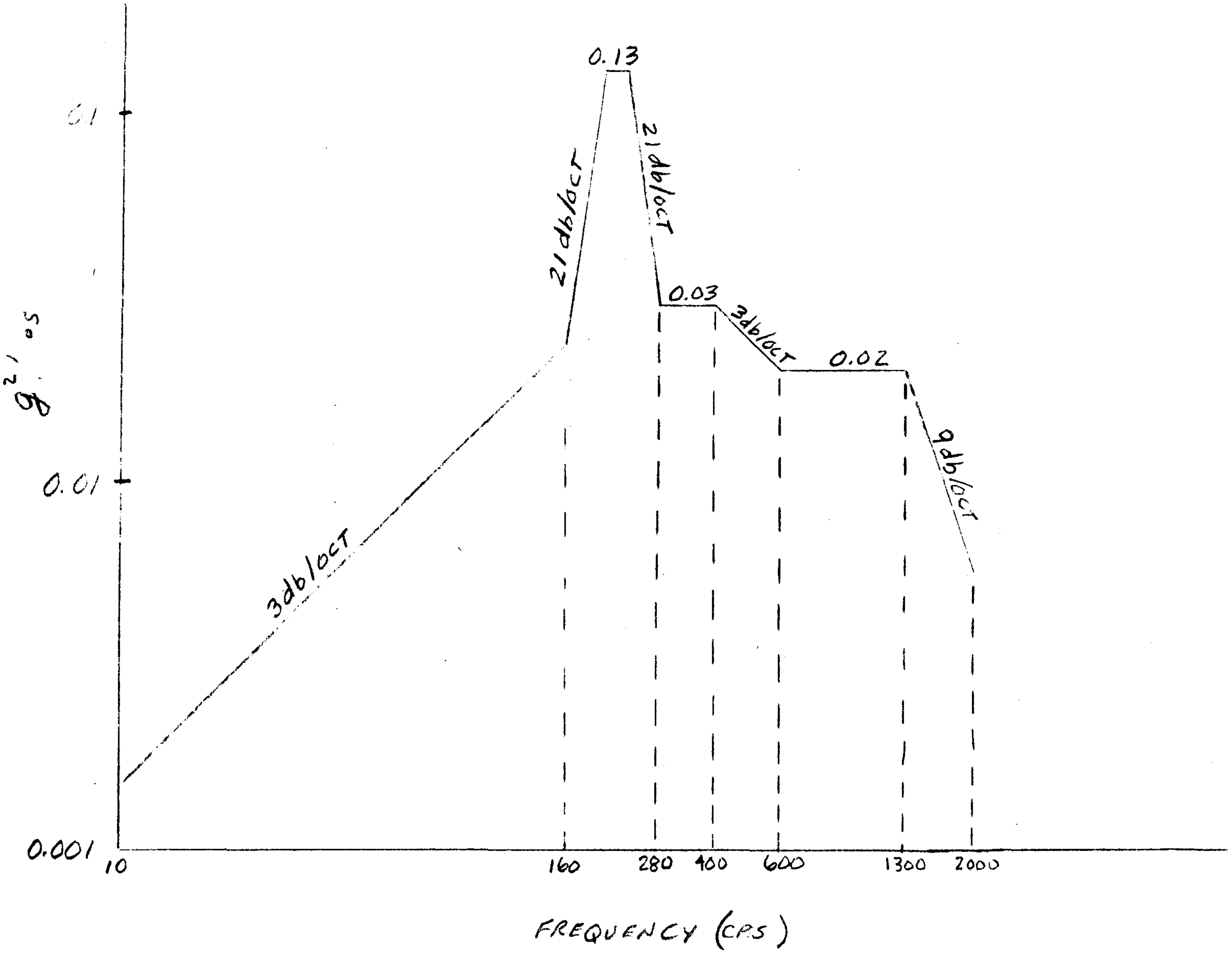


FIGURE 3-4
RANDOM VIBRATION
Y-AXIS

DURATION: AS REQ'D TO
OBTAIN 10 SEC
TAPE LOOP

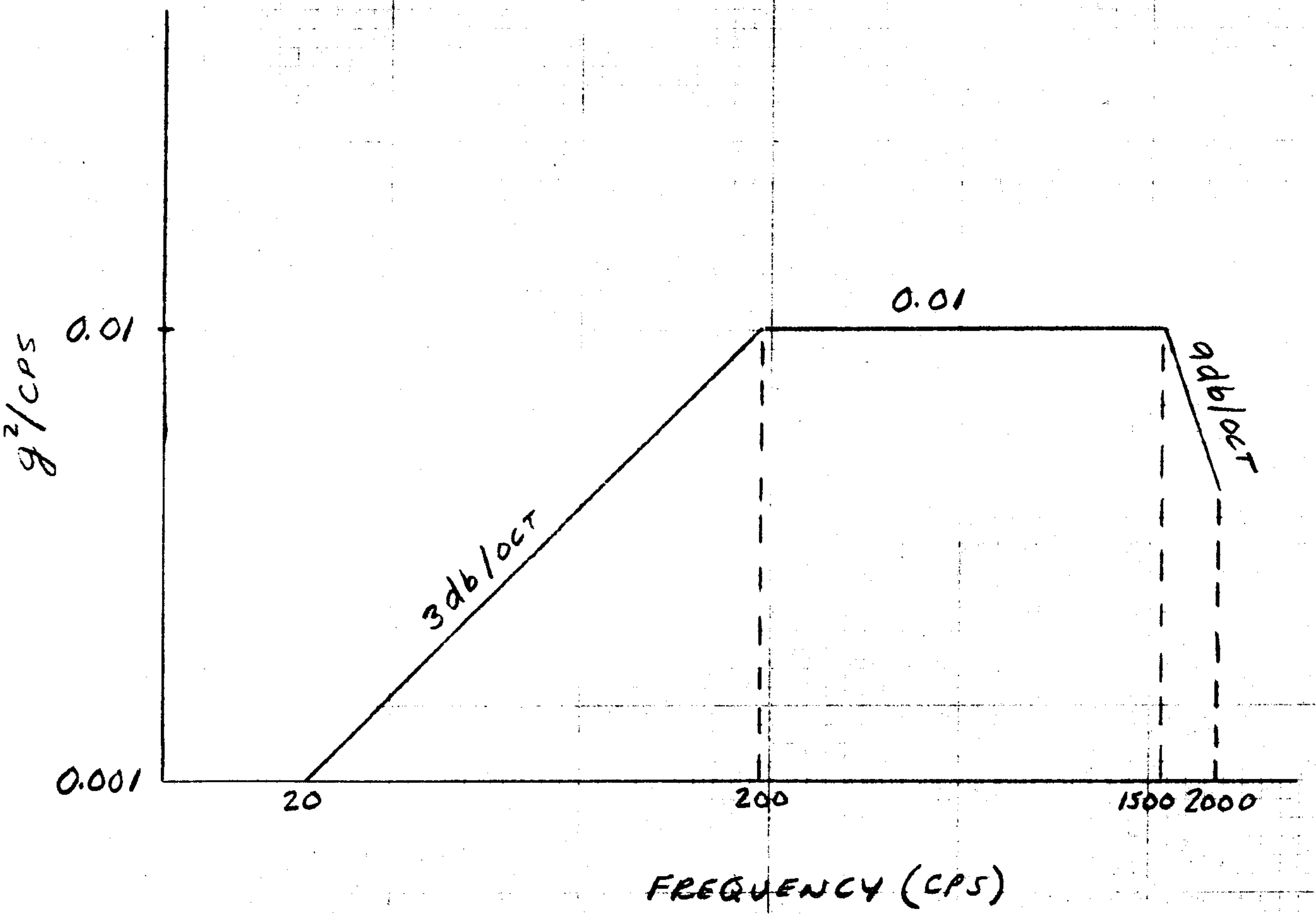
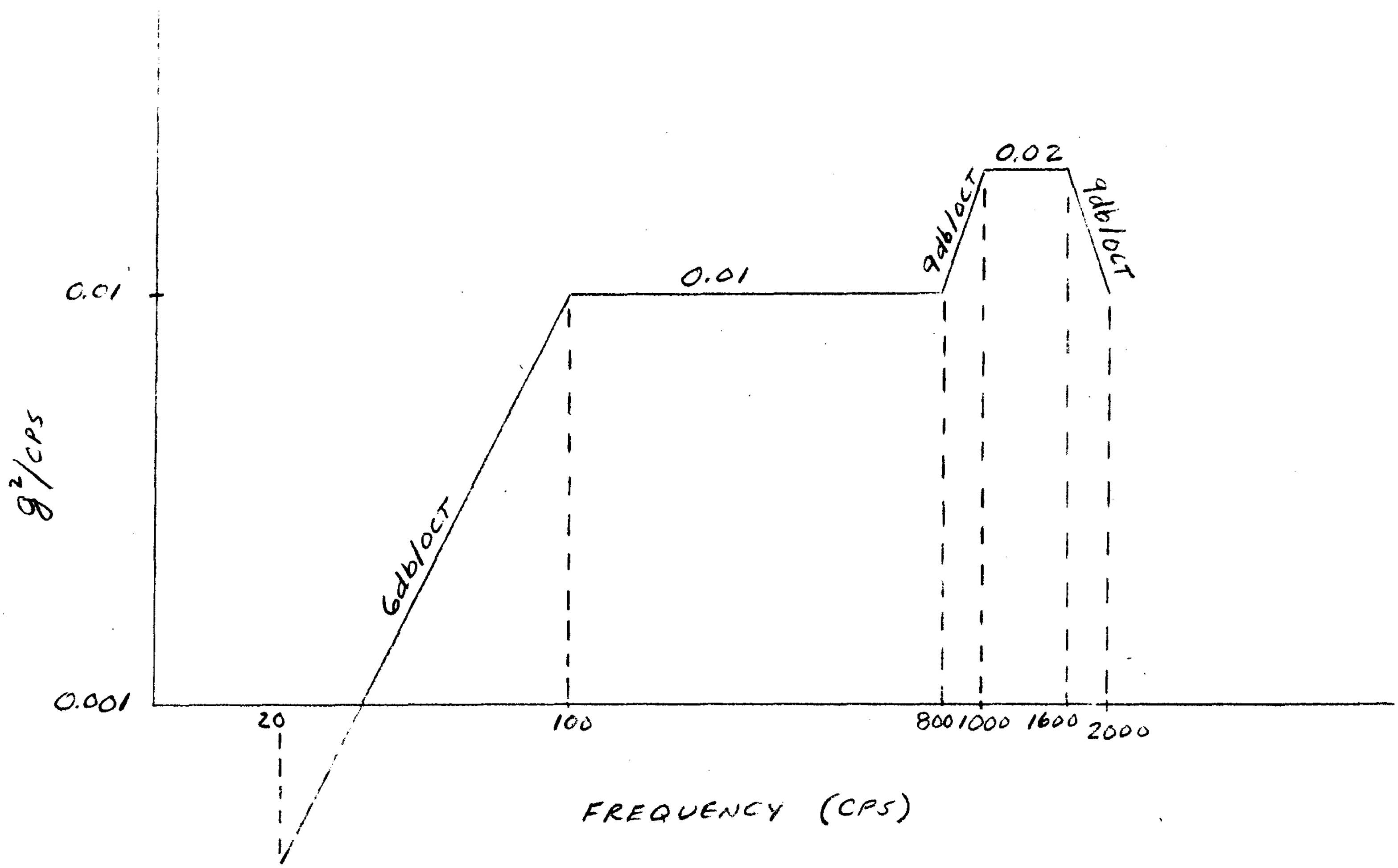
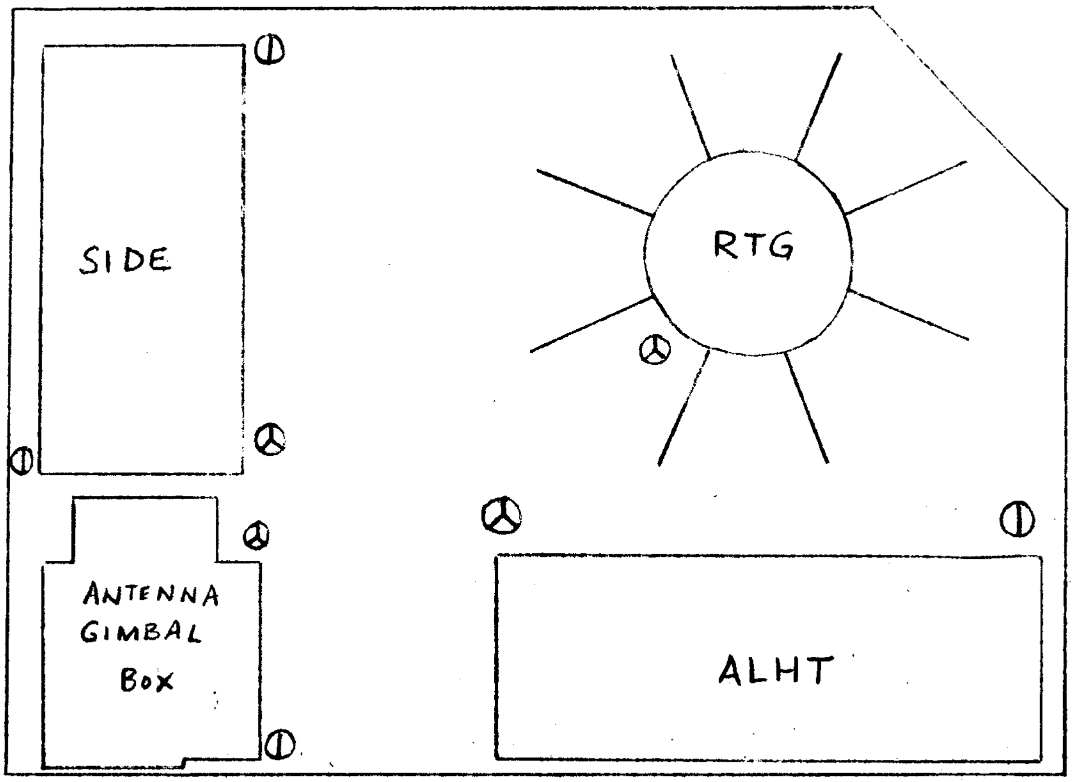


FIGURE 3-5
RANDOM VIBRATION
Z-AXIS

DURATION: AS REQ'D TO
OBTAIN 10 SEC
TAPE LOOP





⦶ SINGLE AXIS ACCELEROMETER (ALIGNED WITH INPUT AXIS)

☮ TRIAXIAL ACCELEROMETER

ACCELEROMETERS LOCATED ON SUB-PALLET OR PALLET, EXCEPT TRIAXIAL FOR SIDE, AS CLOSE TO BENDIX/EQUIPMENT INTERFACE AS POSSIBLE. TRIAXIAL ACCELEROMETER FOR SIDE LOCATED ON SUPPORT BRACKET.

FIGURE 3-6

INSTRUMENTATION LOCATION

SUB PACKAGE 2

3.5 TEST PROCEDURE

The test was run in the following sequence:

Z axis	α_2
	β_2
	γ_2
Y axis	γ_2
	α_2
	β_2
X axis	β_2
	γ_2
	α_2

Each configuration was subjected to the environment described in 3.4. Data from all accelerometers was recorded for the full sinusoidal duration and for the random vibration runs to obtain a 10 sec. tape loop.

4.0 TEST RESULTS

The reduced sinusoidal and random test data is presented in its entirety in ref. 6.4.

In the discussion of the test results the following definitions will be useful:

(1)	T	sinusoidal vibration transmissibility (output acceleration divided by input acceleration)
(2)	ASD	random vibration acceleration spectral density (g^2/cps)
(3)	G_{RMS}	root-mean-square acceleration (the square root of the integral of the ASD vs. frequency curve)

4.1 SINUSOIDAL VIBRATION

Table 4-1 lists the maximum T values, recorded for each subsystem during sinusoidal vibration in each axis, and the corresponding frequency. Two sets of data are shown (one for the α configuration and one for γ) which readily show the consequences of off-loading the SIDE. The only significant change in T_{max} was found at the RTG when vibrated in the x-axis. An increase from 7.5 to 8.0 occurred (+7%).

Table 4-2 lists T_{max} (and frequency) for each subsystem and input direction for the α and β configurations. Comparison of the data shows the consequences of off-loading the ALHT. Very slight increases in T_{max} were seen for the antenna gimbal (GIM.) and the RTG. The only significant increase occurred at the SIDE for the x-axis vibration T_{max} increased from 5.0 to 6.4 (+28%).

4.2 RANDOM VIBRATION

Figures 4-1 to 4-9 show the relative effects of off-loading the SIDE, upon the random response envelopes for each remaining subsystem. A response envelope is obtained by superimposing all the data available for a given subsystem (ALHT, GIM, RTG, SIDE) and a given response direction (x, y, z). This would include "in-axis" and "cross-axis" data from all instrumentation associated with a particular subsystem. Thus, a response envelope represents the worst random environment experienced at any time during the test series.

Comparing α and γ envelopes shows that the ALHT and RTG experienced no significant changes in ASD levels for the x and y response directions. However, significant increases were realized for the ALHT and RTG in the z response direction and for the GIM in all response directions. These differences and the corresponding frequencies are listed in Table 4-3.

Figures 4-10 to 4-18 show the α and β configuration response envelopes for the remaining subsystems when the ALHT was removed. No significant changes in ASD levels occurred for the GIM in the x- and z-response directions, nor for the SIDE in the x-response direction. The β configuration did result in significantly increased ASD levels (relative to the α configuration) for the other cases. These are listed in Table 4-4.

Unfortunately root-mean-square acceleration values (G_{RMS}) associated with the random data is not available. However, by comparing the α and γ envelopes of figures 4-1 to 4-9 and the α and β envelopes of figures 4-10 to 4-18, it is obvious that in most cases the G_{RMS} values differ only slightly and for the worst cases by not more than 15%.

5.0 CONCLUSION

Off-loading the SIDE did not increase the sinusoidal vibration environment of the remaining subsystems by a prohibitive amount. The worst case was an increase of 7 percent. However, at certain frequencies the random vibration environment increased substantially (as high as 800%) for the remaining subsystems. Whether or not such increased random levels would be detrimental depends upon the dynamic characteristics of the subsystems. If some of the subsystem natural frequencies correspond to the frequencies at which the input to the subsystem is increased (as a result of off-loading the SIDE), then severe damage could occur.

Although no structural damage was observed and the G_{RMS} levels were not increased by more than 15%, it is recommended that the SIDE not be off-loaded. The increased ASD levels which would result at certain frequencies represent a potential hazard which should be avoided.

Off-loading the ALHT increased the sinusoidal vibration environment of the SIDE by 28 percent. This represents a substantial increase, but is within the 30 percent factor of safety allowed between qualification (design limit) test levels and expected flight levels.

The random vibration environment to the remaining subsystems, when the ALHT is off-loaded, increased at certain frequencies by 100 percent which exceeds the 69 percent factor of safety (for random ASD values) allowed between qualification test levels and expected flight levels. The simularity between the α and β ASD curves indicates that the removal of the ALHT did not increase the G_{RMS} values significantly.

No structural damage was observed due to the vibration tests conducted with the ALHT off-loaded.

Although their exists a potential hazard to the hardware due to increased dynamic loading as a result of off-loading the ALHT, the data indicates that the hazard is much less than it would be if the SIDE were removed.

A firm recommendation to off-load the ALHT (or any subsystem), based upon a comparative test such as the one conducted, could be made only if the vibration data for the off-loaded configuration showed response levels which did not exceed those for the full configuration. This was not the case. Therefore, a firm recommendation to off-load cannot be given.

Since off-loading does increase the dynamic environment of the remaining subsystems, the only way to be sure that those subsystems will not be damaged would be to conduct a qualification test using qualification hardware in the off-loaded configuration.

If such a qualification test is not feasible and a situation arises where a subsystem must be off-loaded or the entire ALSEP system will be removed the the LM, then it may be desireable to off-load a subsystem and assume the risk involved. In this case the results of this report and ATM-802 (off-loading subpackage #1) can be used to minimize the risk. Since the least increase in dynamic environment to the ALSEP subsystems occurs if the ALHT is removed, the risk would be minimized by off-loading the ALHT.

TABLE 4-1 COMPARISON OF SINUSOIDAL TEST DATA — α & γ CONFIGURATIONS

SUBSYSTEM	RESPONSE DIRECTION	α		γ	
		T_{MAX}	FREQ.	T_{MAX}	FREQ.
ALHT	X	7.6	56 cps	7.5	57 cps
	Y	1.3	38	1.3	46
	Z	2.0	56	1.4	56
GIM.	X	6.0	60	4.8	57
	Y	1.4	38	1.4	62
	Z	2.8	61	1.4	56
RTG	X	7.5	58	8.0	58
	Y	1.3	44	1.4	48
	Z	1.4	75	1.6	80

TABLE 4-2 COMPARISON OF SINUSOIDAL TEST DATA — α & β CONFIGURATIONS

SUBSYSTEM	RESPONSE DIRECTION	α		β	
		T_{MAX}	FREQ.	T_{MAX}	FREQ.
GIM.	X	6.0	60 cps	6.1	56 cps
	Y	1.4	38	1.3	35
	Z	2.8	61	1.5	60
RTG	X	7.5	58	7.7	58
	Y	1.3	44	1.3	50
	Z	1.4	75	1.6	100
SIDE	X	5.0	58	6.4	82
	Y	2.2	40	2.1	38
	Z	2.9	95	2.7	100

TABLE 4-3 COMPARISON OF RANDOM TEST DATA (α & γ)

SUBSYSTEM	RESPONSE DIRECTION	FREQUENCY (CPS)	ASD (g^2/CPS)	
			γ	α
ALHT	Z	460	0.085	0.022
GIM	X	270	0.048	0.023
	X	800	0.145	0.049
	Y	740	0.135	0.070
	Z	460	0.056	0.014
	Z	780	0.155	0.018
RTG	Z	460	0.060	0.022

TABLE 4-4 COMPARISON OF RANDOM TEST DATA (α & β)

SUBSYSTEM	RESPONSE DIRECTION	FREQUENCY (CPS)	ASD (g^2/CPS)	
			β	α
GIM	Y	360	0.051	0.025
RTG	X	100	0.095	0.047
	Y	460	0.067	0.045
	Z	330	0.058	0.035
SIDE	Y	460	0.054	0.035
	Z	300	0.082	0.052

FIG. 4-1

ALHT X-RESPONSE

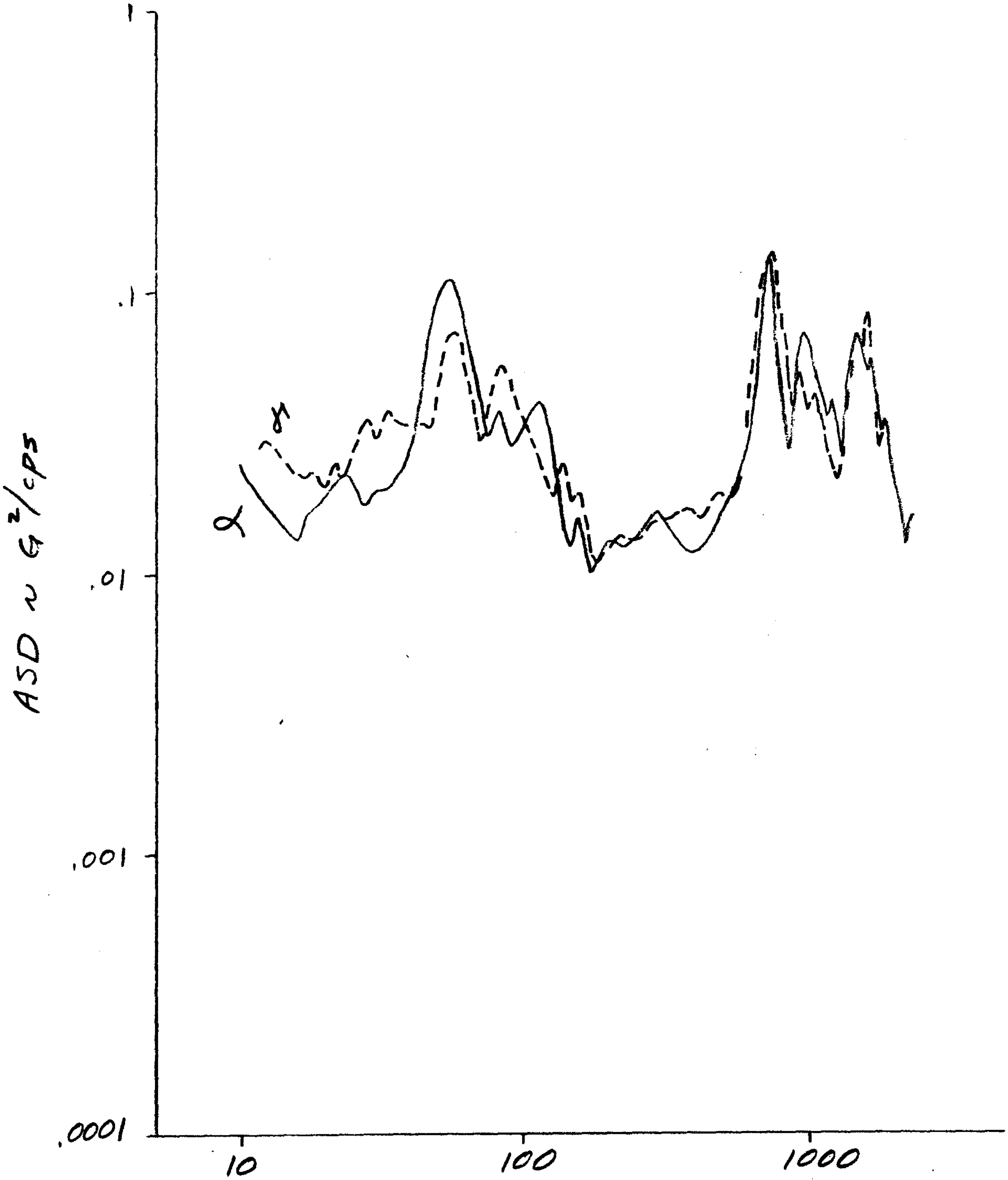


FIG. 4-2

ALHT Y-RESPONSE

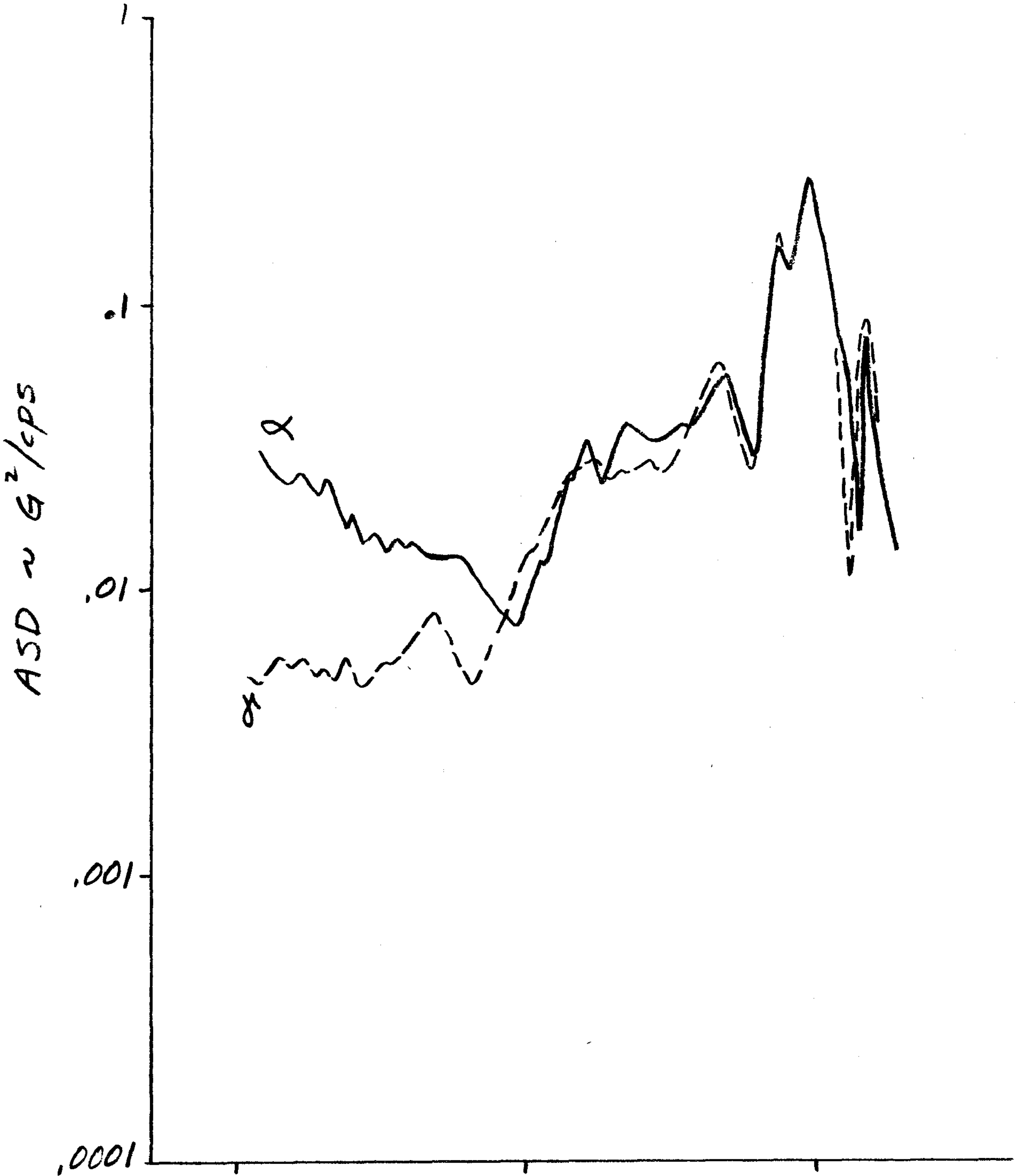


FIG. 4-3

ALHT Z-RESPONSE

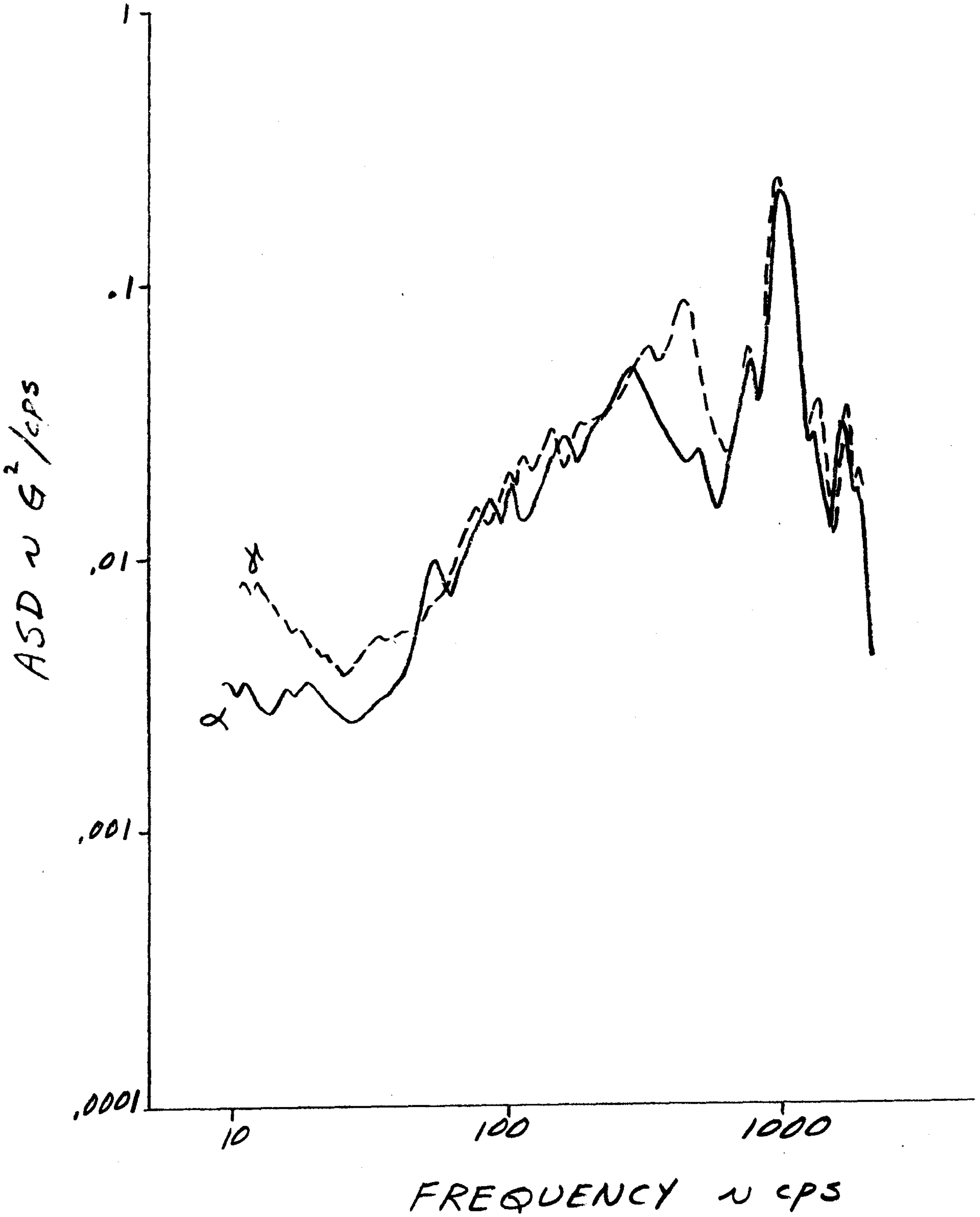


FIG. 4-4

GIMBAL X-RESPONSE

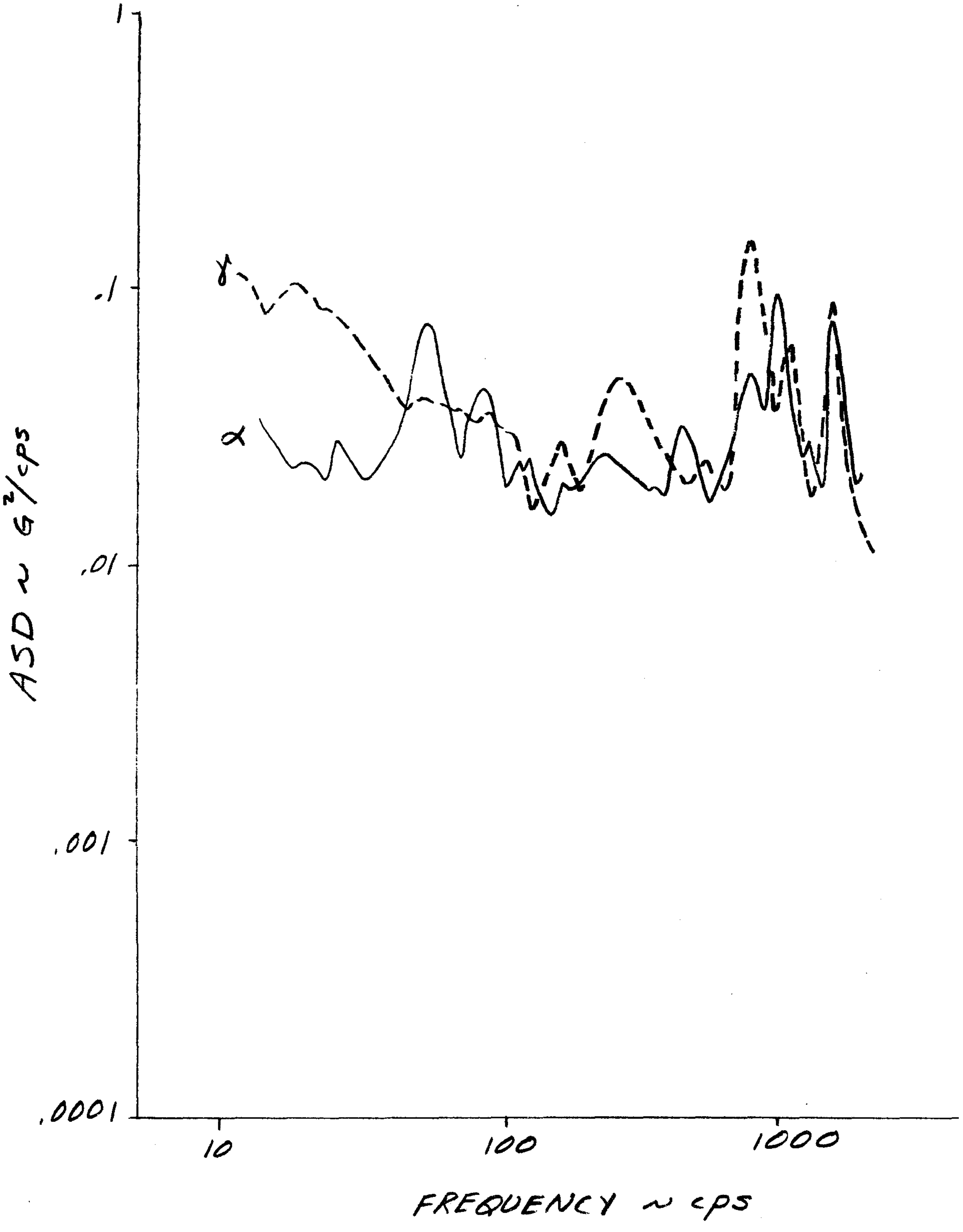


FIG. 4-5

GIMBAL Y-RESPONSE

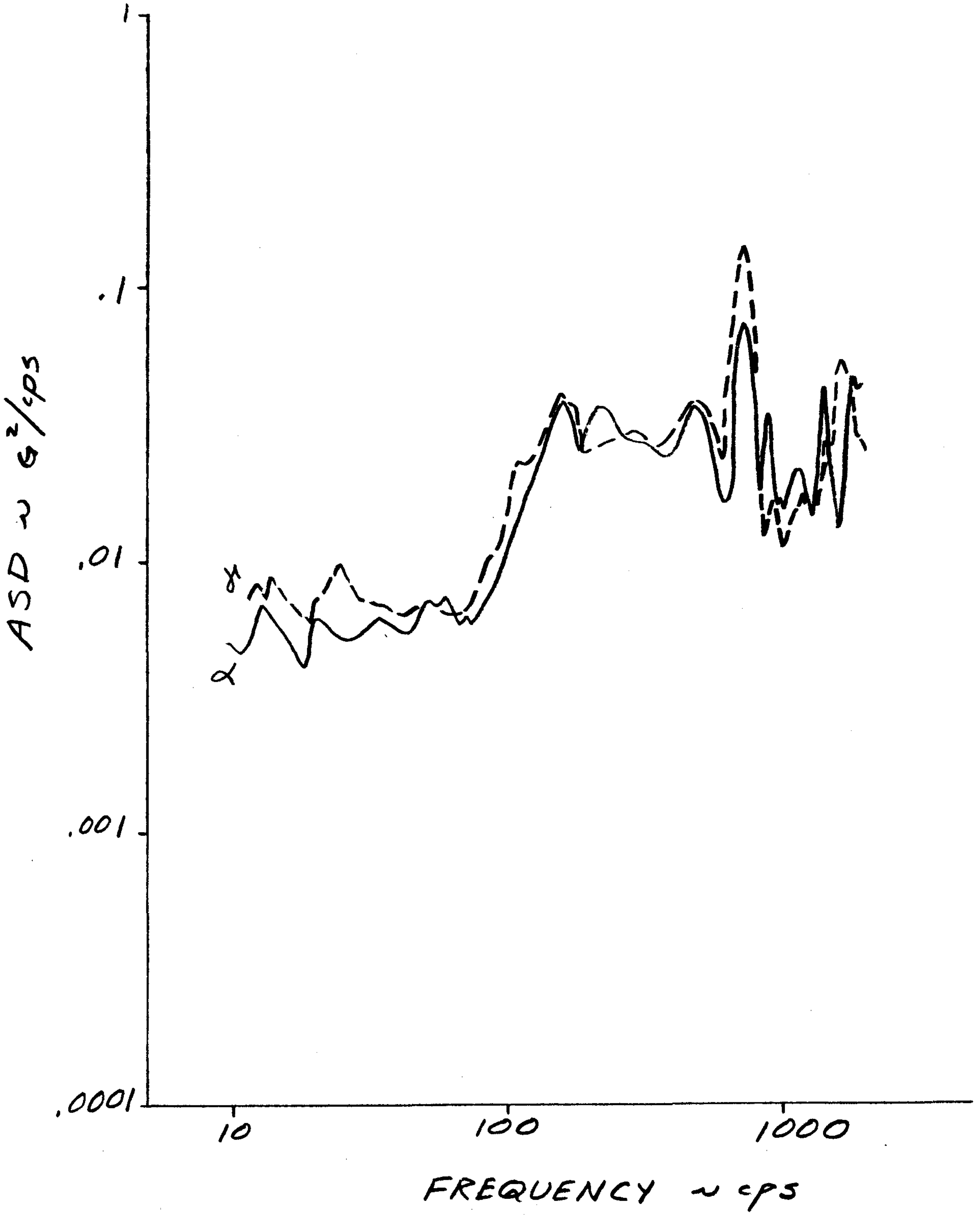


FIG. 4-6

GIMBAL Z-RESPONSE

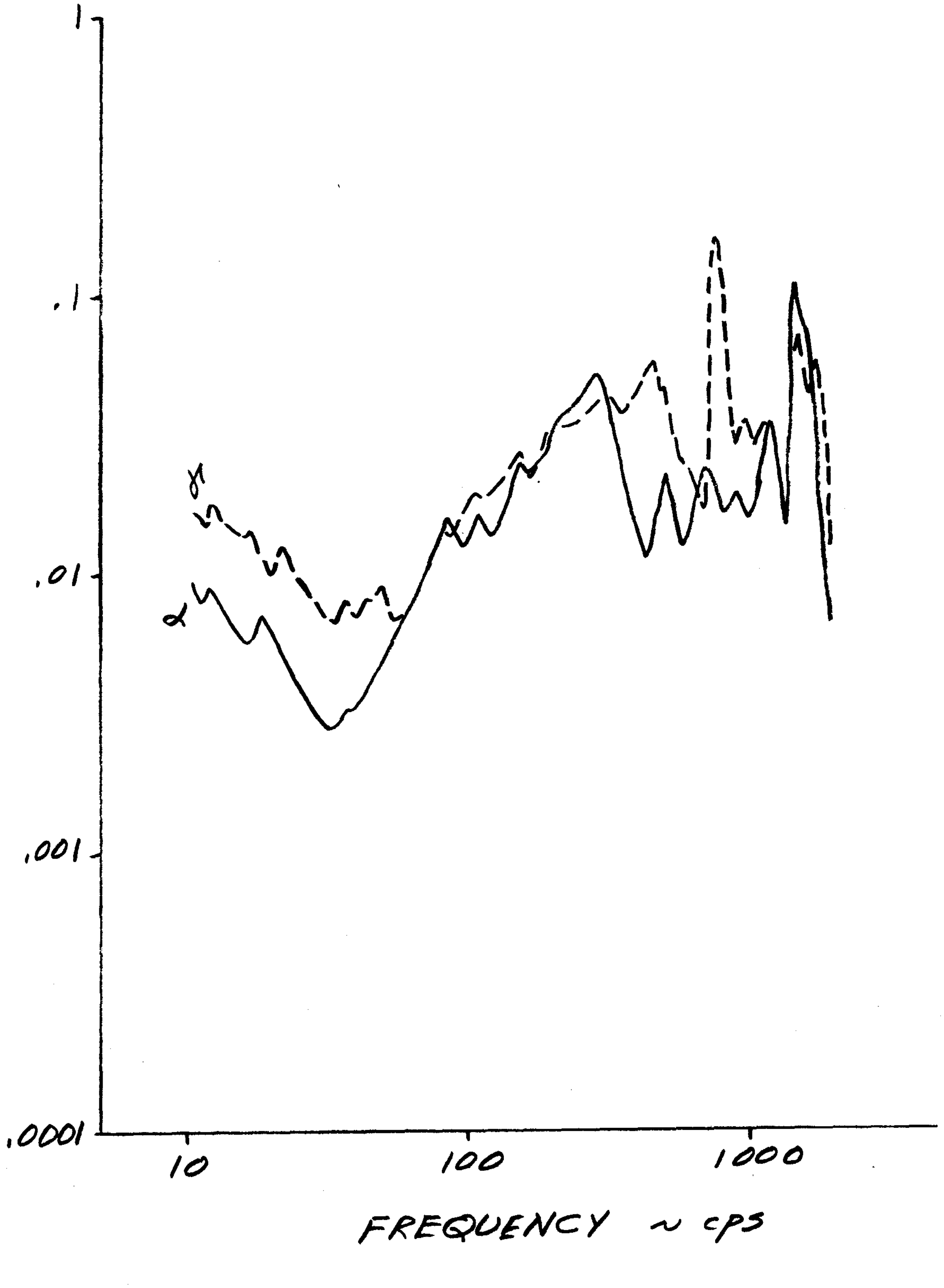


FIG. 4-7

RTG X-RESPONSE

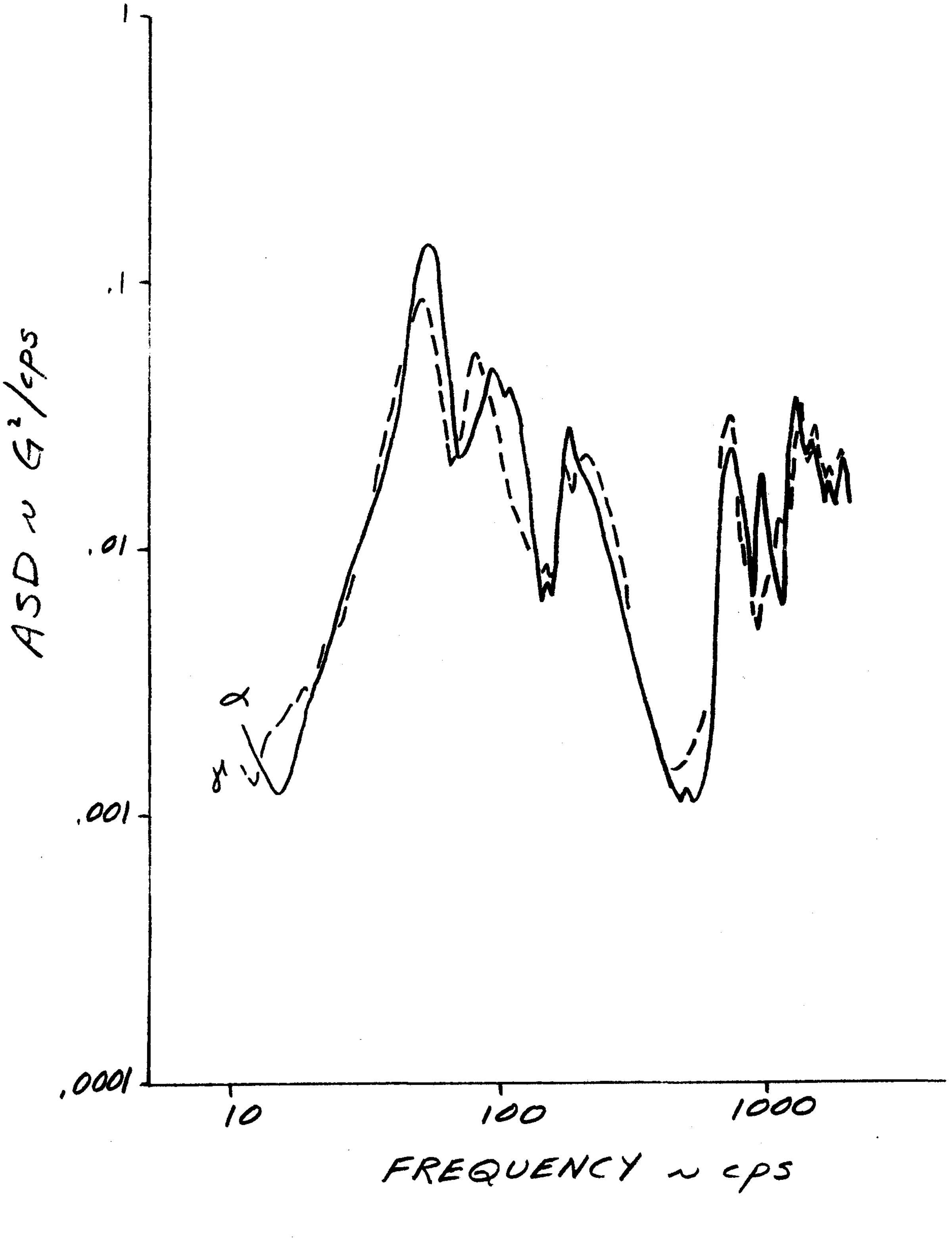


FIG. 4-8

RTG Y-RESPONSE

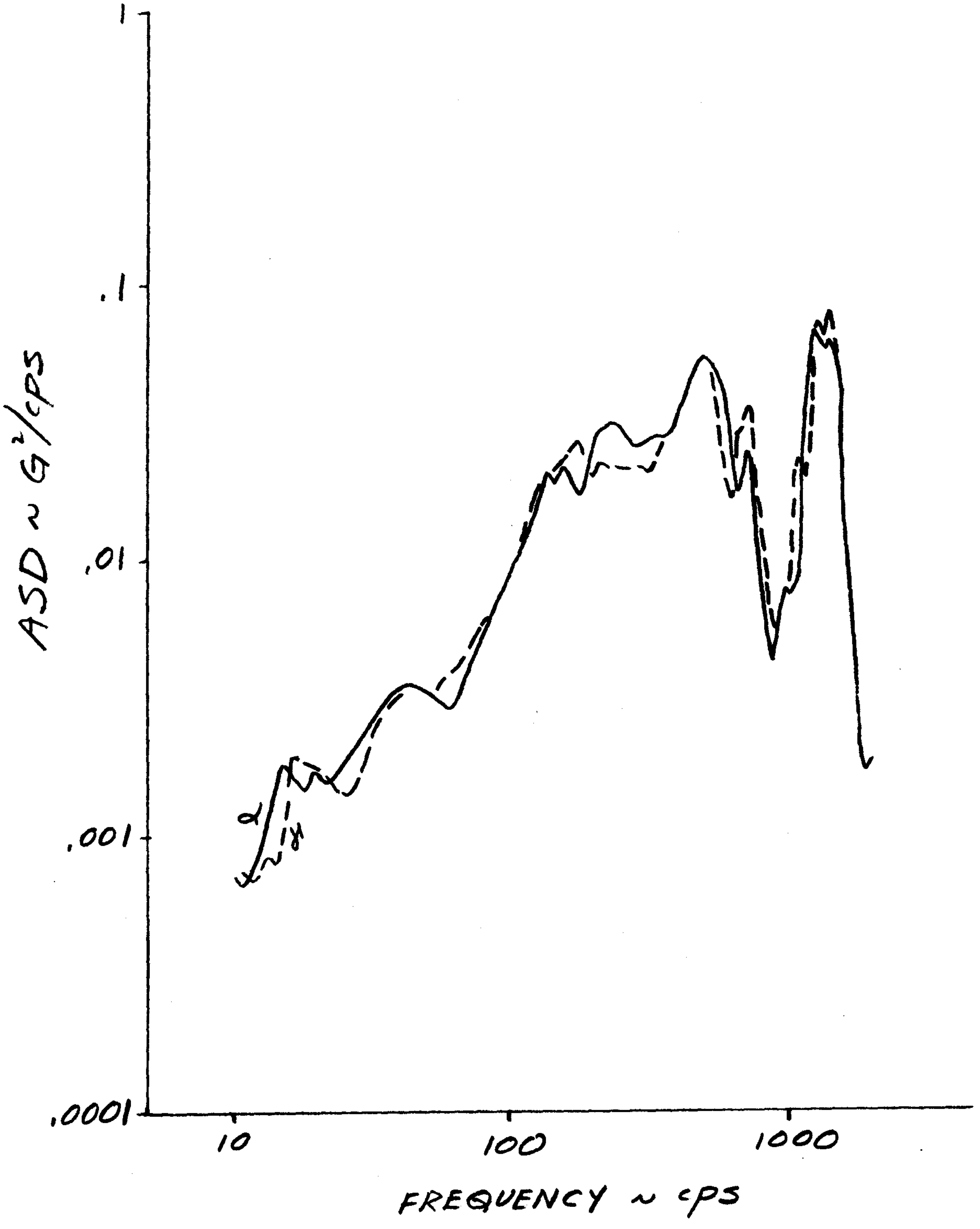


FIG. 4-9

RTG Z-RESPONSE

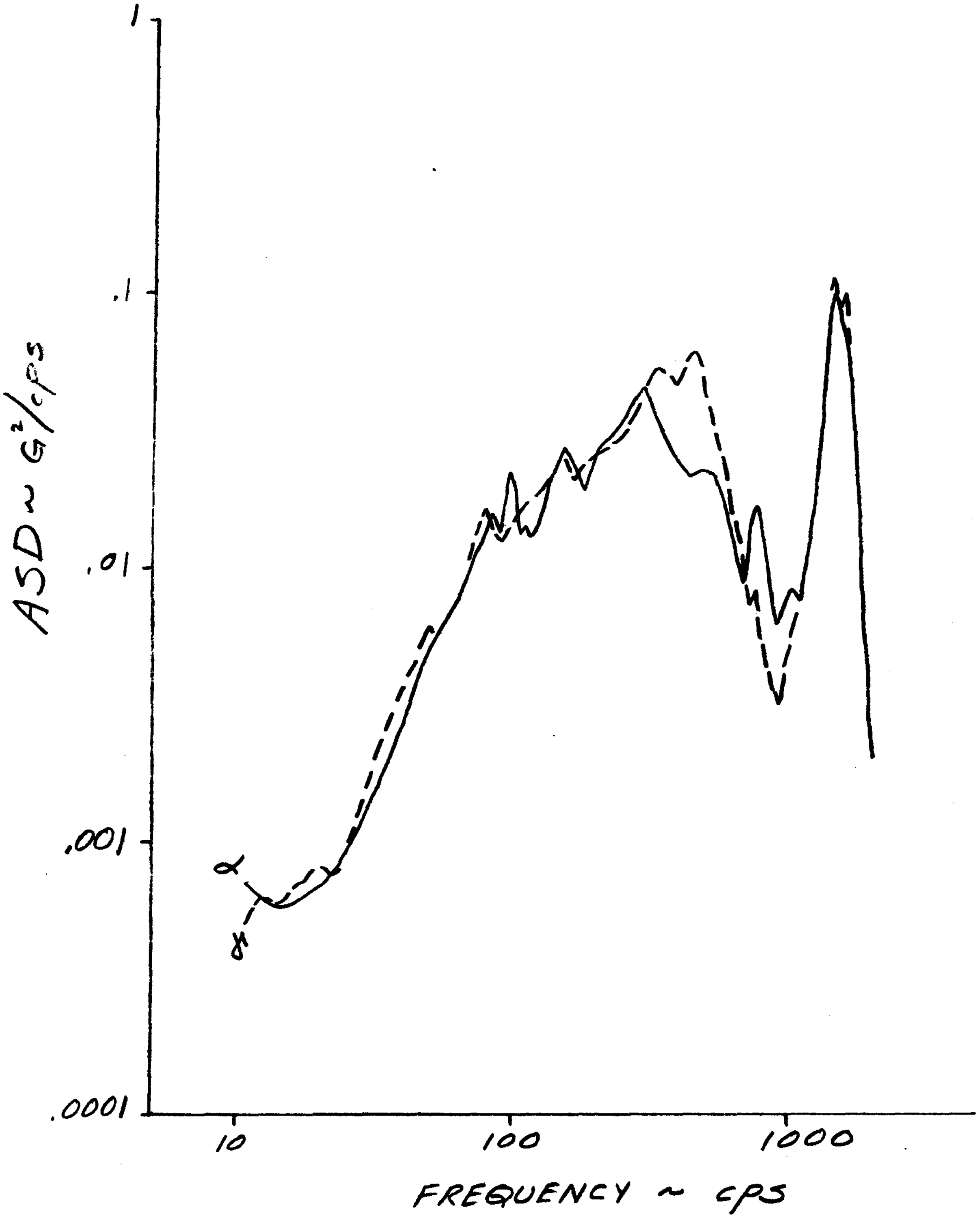


FIG. 4-10

GIMBAL X-RESPONSE

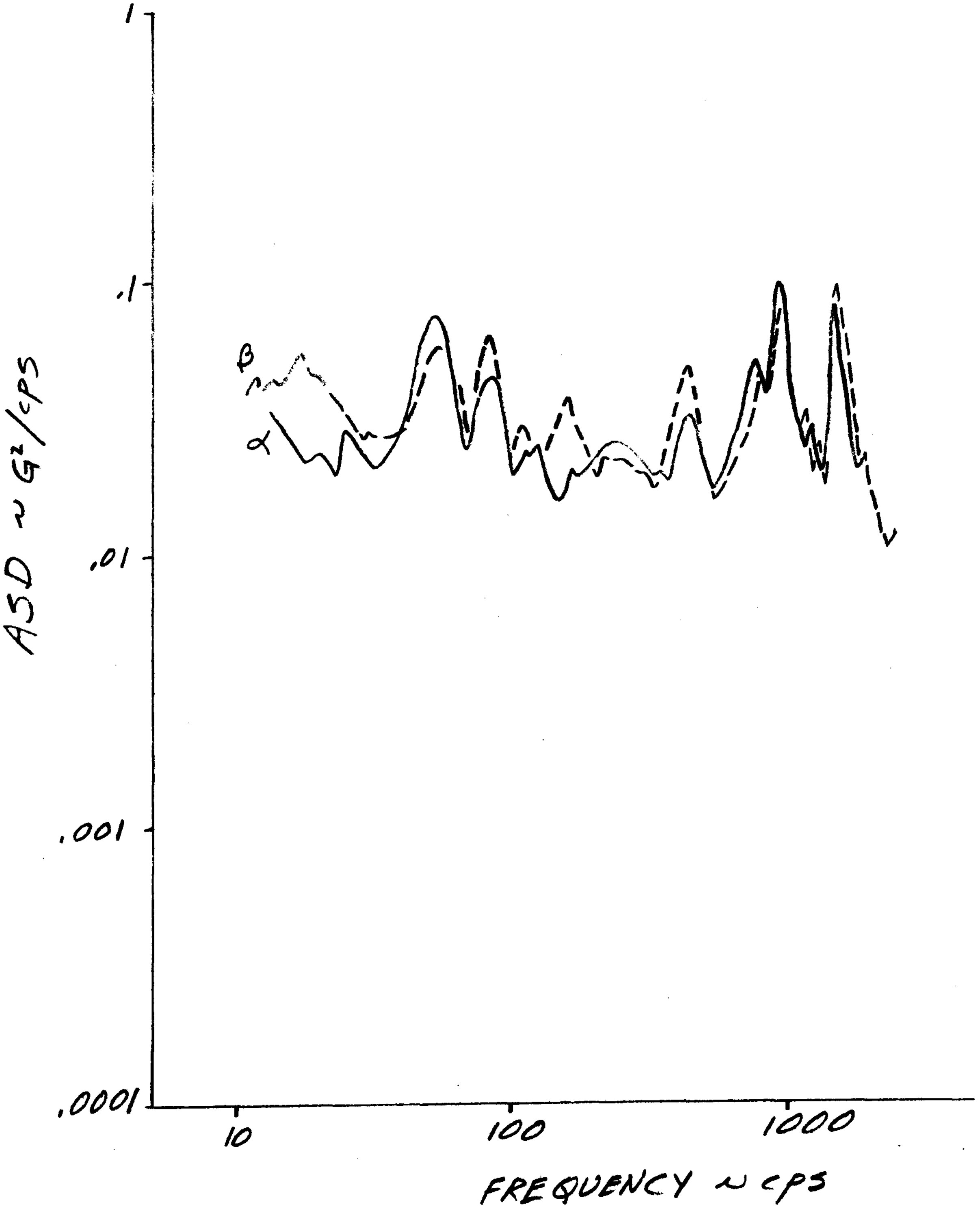


FIG. 4-11

GIMBAL Y-RESPONSE

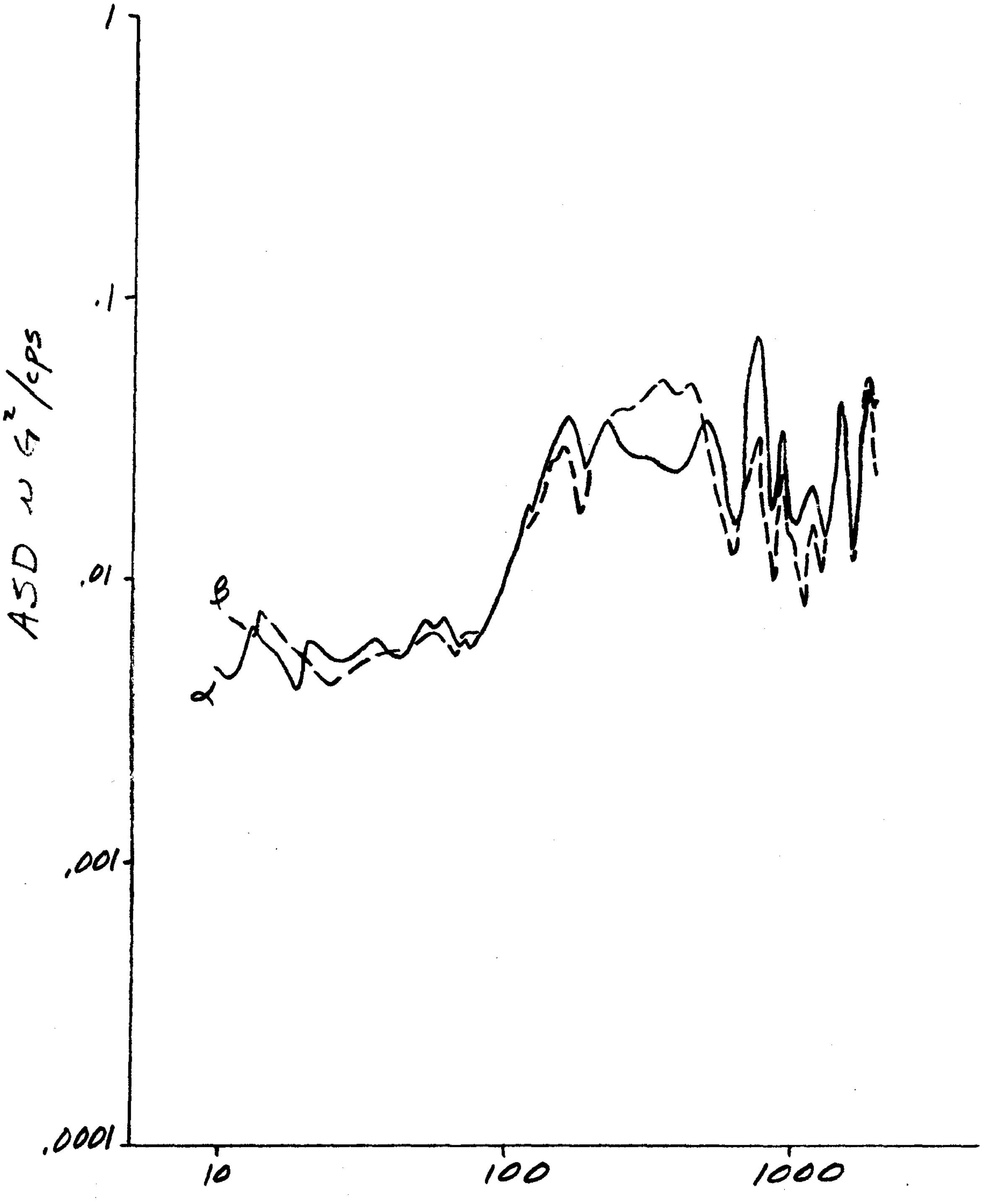


FIG. 4-12

GIMBAL Z-RESPONSE

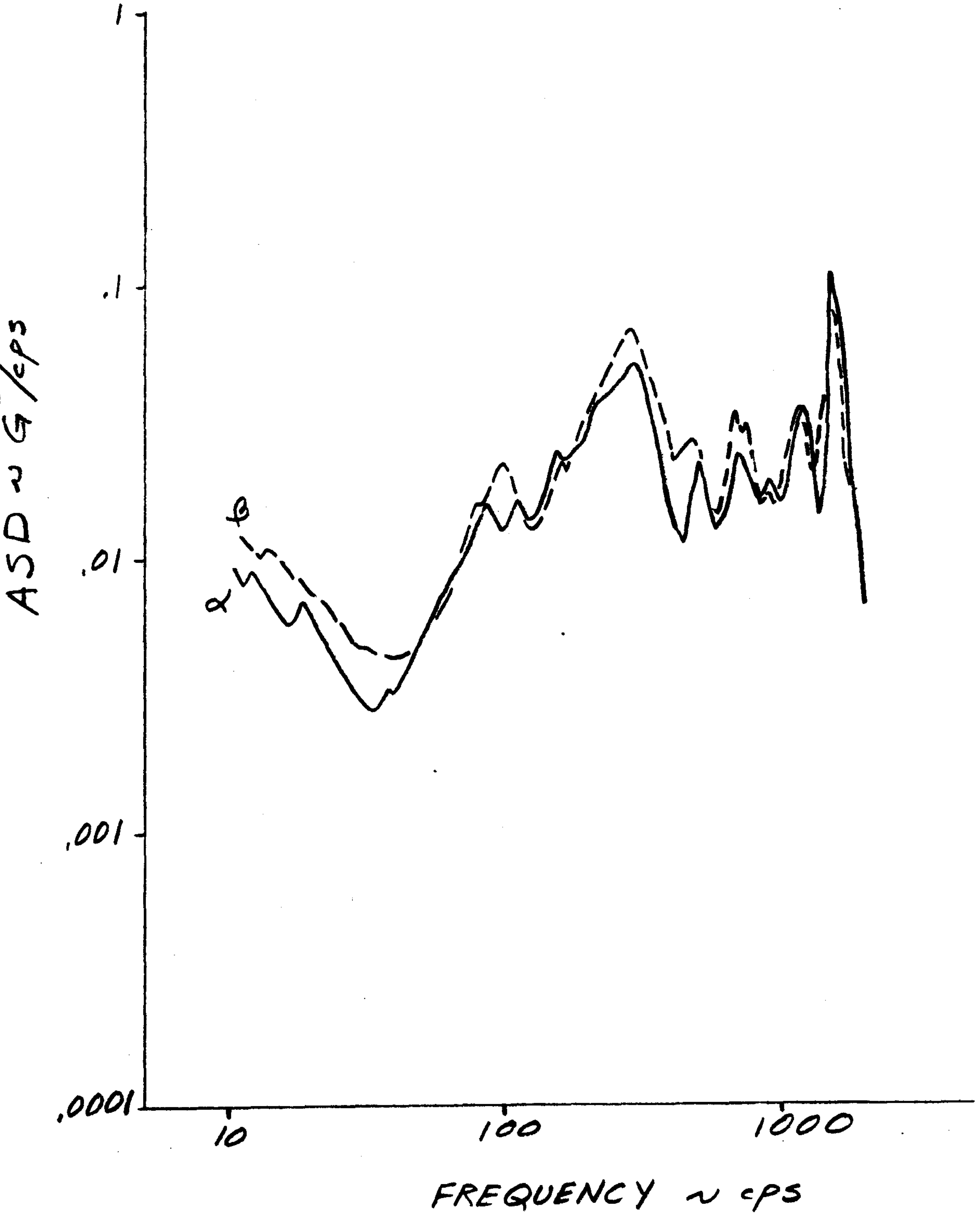


FIG. 4-13

RTG X-RESPONSE

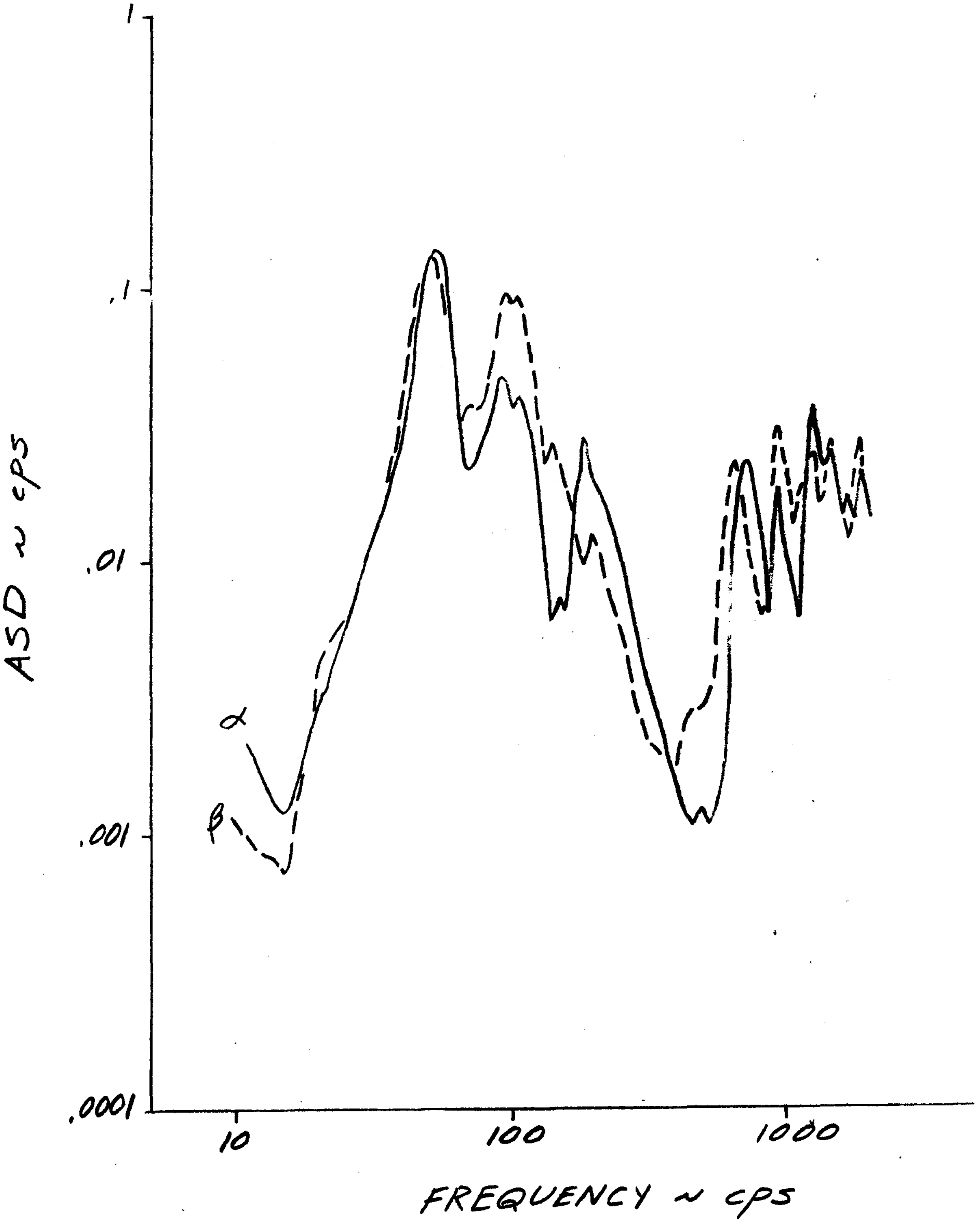


FIG. 4-14

RTG Y-RESPONSE

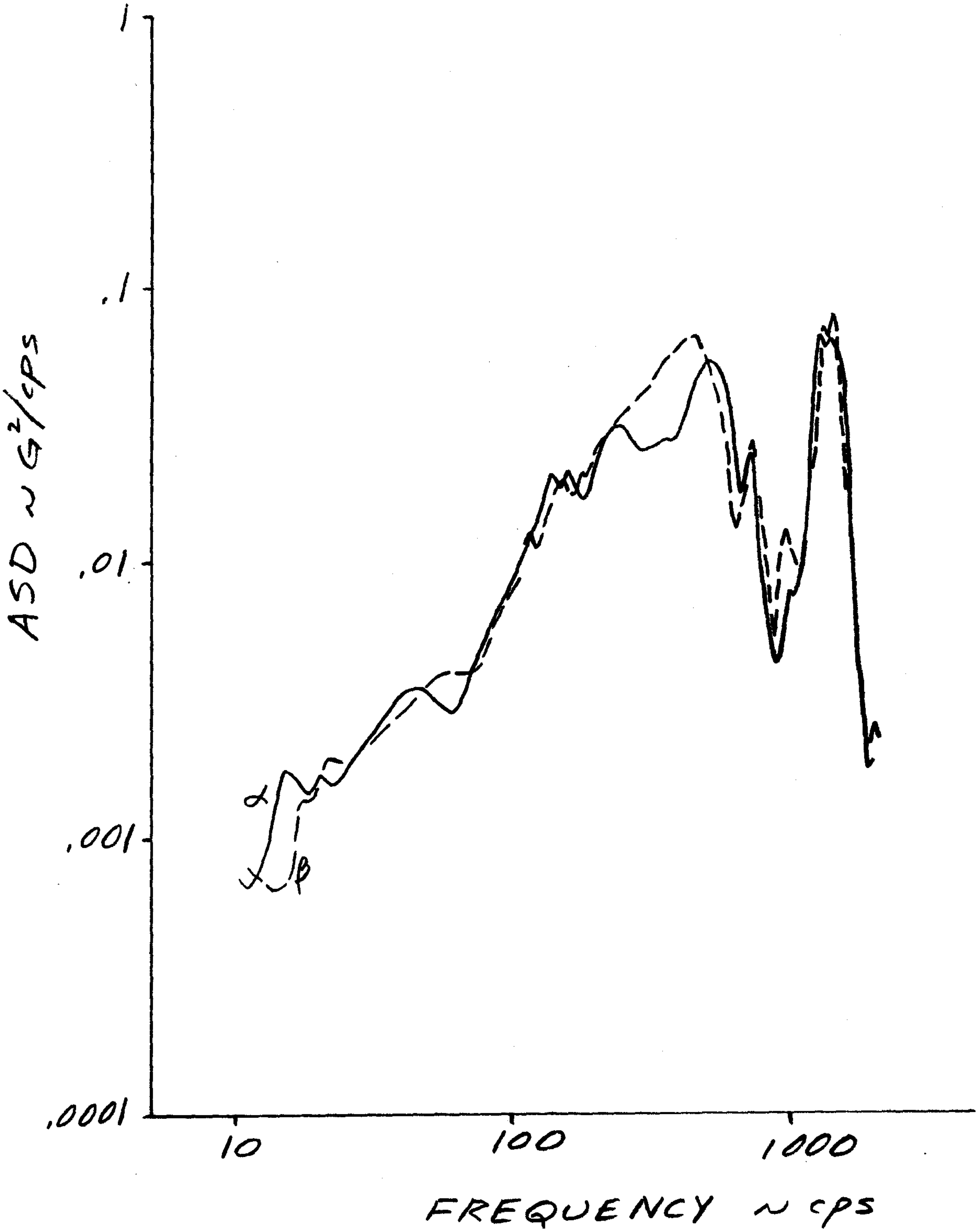


FIG. 4-15

RTG Z-RESPONSE

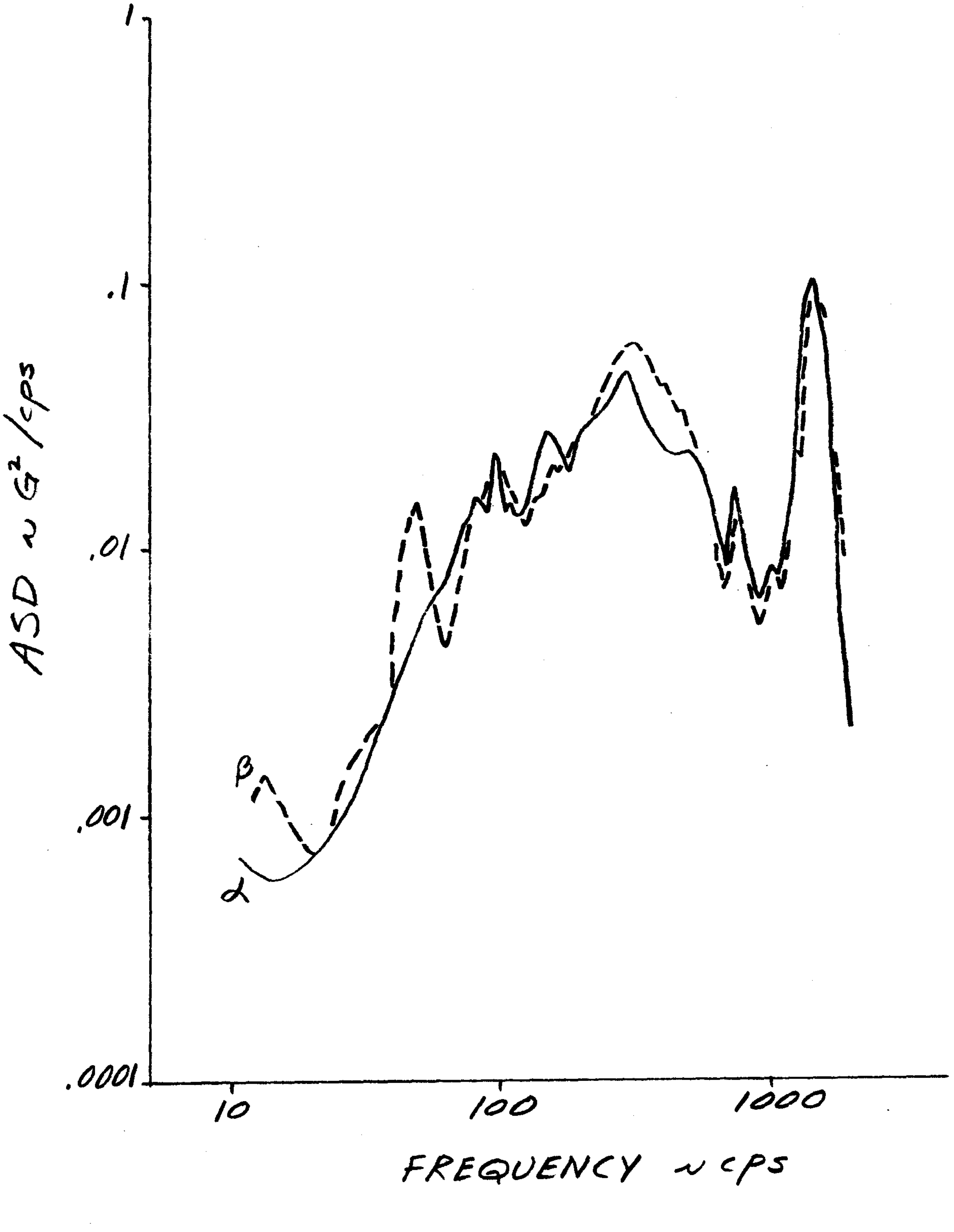


FIG. 4-16

SIDE X-RESPONSE

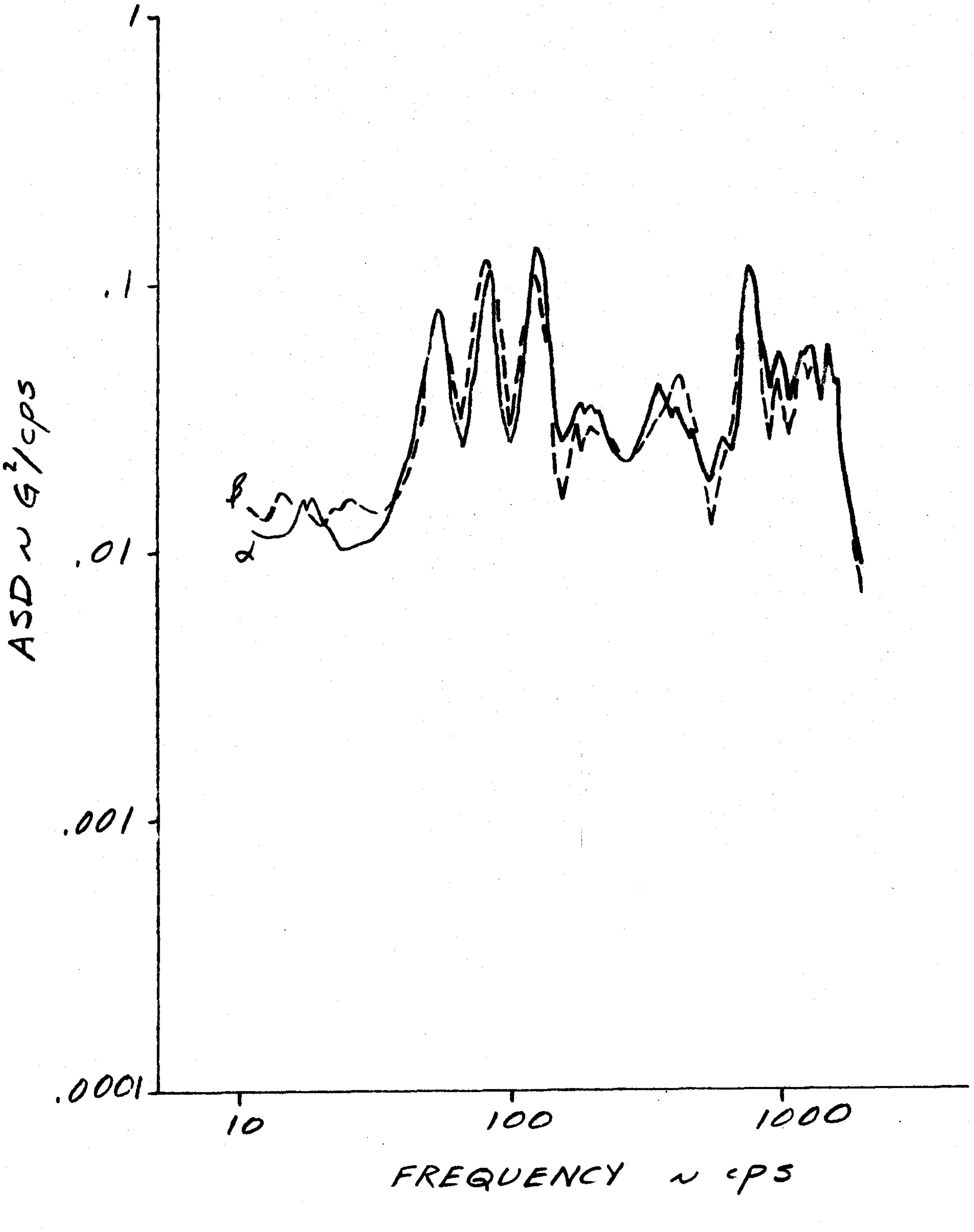


FIG. 4-17

SIDE Y-RESPONSE

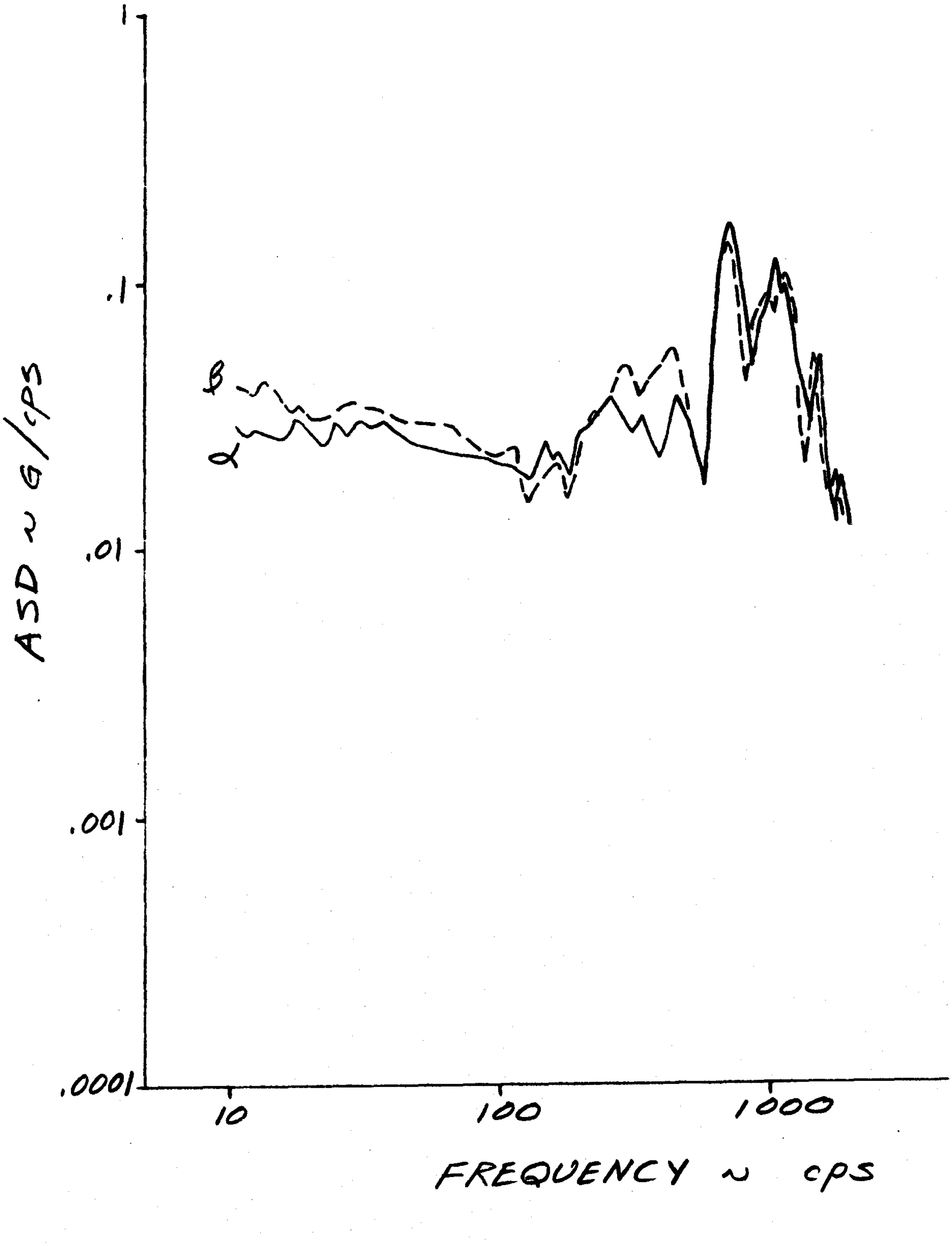
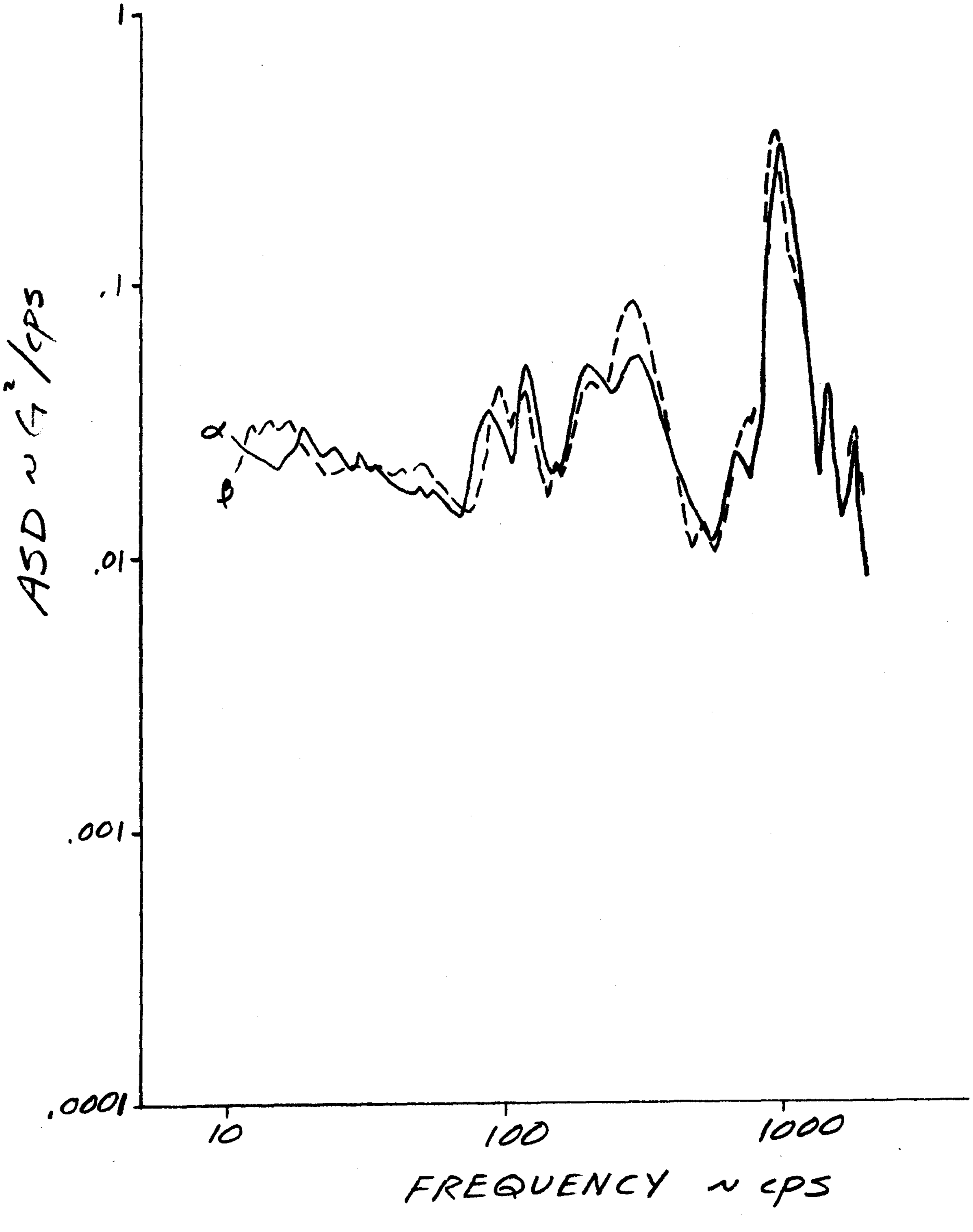


FIG. 4-18

SIDE Z-RESPONSE



6.0 REFERENCES

The following documents are references applicable to the test program reported herein.

6.1 NASA TWX BG 741/T60/2-20 Attn: R. A. Long, Subject: Contract NAS9-5829 CCP98 dated 2-26-68.

6.2 Bendix AER 63, Flight Off-Loading Program for Array A, dated 29 March 1968 (Bendix Memo 9712-755 dated 3-28-68)

6.3 Bendix Memo 9712-828, Addendum to Test Requirements for Off-Loading Program - Array A, dated 4-22-68.

6.4 Bendix TR 3164, 19 Sep. 1968

6.5 Bendix Dwg 2334849, Subpackage 2 Assembly Array A (as a reference only, since it does not define the specific Subpackage 2 assembly tested).

6.6 Bendix Dwg 2338200 (Rev A) SN-2, Pallet Subpackage II Modified.

6.7 Bendix Dwg. 2334290 (Rev G) Subpallet Assy, Subpackage II.

6.8 Bendix Dwg 2338461, Modification - Subpallet Assy - Subpackage II Off-Load Tests.

6.9 Bendix Dwg. 2333270 (Rev G), Structure Assembly - Sub-Pallet.

6.10 Bendix Dwg. 2330268 (Rev A), Shield/RTG Cable Stowage.

6.11 Bendix Dwg. 2334282 (Rev A), RTG Cable Spool Assy

6.12 Bendix Dwg. 2333303, Package-Aiming Mechanism

6.13 Bendix Dwg. 2330309, Aiming Mechanism

6.14 Bendix Dwg. BSX 7664, Forward Tool Mounting Bracket and Ballast

6.15 Bendix Dwg. BSX 7665, Simulated Tool-Middle Ballast

6.16 Bendix Dwg. BSX 7666, Simulated Tool-Rear Ballast.

6.17 Bendix ATM-792, Fastener Reduction Vibration Test Program for ALSEP Array A, 30 July 1968.

6.18 Bendix ATM-802, Flight Off-Loading Qual Confidence Program for Array A ALSEP Subpackage 1, 23 Sep. 1968.