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VIBRATION AND ACOUSTIC TESTING OF TOPEX/POSEIDON SATELLITE[1]

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ABSTRACT

The satellite was subjected to a 1.5G swept sine vibration test and a 146 dB overall level acoustic test, in accordance with Ariane launch vehicle requirements, at the NASA Goddard Space Flight Center. Extensive pretest analysis of the sine test was conducted to plan the input notching and to justify vibration testing the satellite only in the longitudinal axis. A unique measurement system was utilized to determine the six components of interface force between the shaker and the satellite in the sine vibration test. The satellite was heavily instrumented in both the sine vibration and acoustic test in order to insure that the launch loads were enveloped with appropriate margin and that satellite responses did not exceed the compatibilities of the structure and equipment. The test specification, objectives, instrumentation, and test results are described herein.

INTRODUCTION

TOPEX (Ocean **TOP**ography **EX**periment)/Poseidon is a collaborative mission between the United States and France. Its purpose is to obtain highly accurate measurements of global sea level to improve understanding of ocean circulation and its impact on the environment.

The satellite was developed by Fairchild Space Company and launched by an Ariane 42P rocket from Arianespace launch facilities at Kourou, French Guiana. The Jet Propulsion Laboratory has overall project management responsibility in addition to providing five payload sensors for the satellite.

[1]The work described in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

The TOPEX/Poseidon flight satellite was subjected to sinusoidal vibration and acoustic noise as part of its system level qualification acceptance test program. The tests were conducted in the facilities of the Goddard Space Flight Center over the period of January 21 through February 5, 1992.

These sine and acoustics tests, run at protoflight levels, satisfy the respective JPL institutional requirements for a Class B mission as well as those of Arianespace - provider of the launch vehicle.

DESCRIPTION

Sinusoidal Vibration

The satellite, in its launch configuration, and with propellant tanks filled with water was subjected to a single, longitudinal axis, of swept sinusoidal vibration (Fig. 1). The inputs in the sine tests were notched to limit the responses at a number of critical positions to limits based primarily on structural capability. Three levels were performed in the sequence up to and including protoflight (1.5 g_{o-pk}). The two preliminary levels were 0.25 g and 0.75g. For each sine level the frequency band was 5-100 Hz and the sweep rate was 4 octaves per minute going from the lower to the upper frequency only. The protoflight test provided a margin of 1.5 over previously measured payload/Ariane 4 interface flight levels.

Just prior to and again immediately following the sine vibration sequence the satellite was subjected to a very low level unnotched random vibration excitation. The purpose of these two runs was to provide a diagnostic comparison of pre- and post-sine satellite responses as a means of detecting any structural degradations. The applied levels were 0.0002 g^2/Hz across the frequency band of 4-400 Hz which is an overall level of 0.28g_{rms}.

Acoustics

The satellite was in its launch configuration. Its LVA was mounted to the TOPEX/Galileo dolly through the vibration adapter ring. This entire assemblage was placed in the Goddard 1100m^3 reverberant acoustic chamber.

The acoustic 1/3 octave spectrum for this test was based on measurements taken during a recent flight of an Ariane-4. This spectrum is compared in Figure 2 with the original spectrum upon which TOPEX design was based, and with the data from the recent Ariane 4 flight. The protoflight test generally provided a 4 dB margin over the maximum expected flight levels.

The acoustics test was conducted in three incremental steps; -12dB, -6dB and finally, the full protoflight level. The two preliminary runs were with the PF acoustic levels reduced uniformly in each 1/3 octave band, i.e., each lowered 12dB or 6dB, respectively. Following each of these runs, all accelerometer data were analyzed; primarily to assess the potential for exceeding the random vibration input, at higher acoustic levels, to any assemblies above that to which they had been qualified. The protoflight test duration was one minute.

OBJECTIVES

Sine Vibration

The stated objectives of the satellite system sine vibration test were:

> to verify that the flight satellite will withstand the low frequency, transient vibration environment associated with launch, and
>
> to verify workmanship of the fully assembled flight satellite.

A secondary "objective" of the system vibration test was to "qualify" those satellite integration elements and interconnections which cannot be dynamically tested at any lower level of assembly.

Acoustics

The stated objectives of the satellite system acoustics test were:

> to verify that the flight satellite is able to withstand the launch vibroacoustic environment without physical or functional performance degradation,
>
> to verify workmanship of the fully assembled flight satellite, and
>
> to assess the adequacy of assembly random vibration criteria.

The secondary objective described above for the sine test also applies to acoustics

INSTRUMENTATION

Sine Vibration

For the sine vibration test the satellite was instrumented with 125 accelerometers in addition to 16 strain gages and four force washers on the solar array. The three primary control accelerometers were located on the fixture baseplate at the LVA interface.

A unique feature of this test setup was a force gage plate assembly which was installed between the C220 shaker and the vertical shaker head expander. These four gages allowed force in each orthogonal axis to be measured, and, from this, moments and torsion at the shaker head plane could also be derived. The need for these measurements came about as a result of the project decision not to use a large existing JPL spacecraft longitudinal vibration fixture with lateral restraint system. Analysis had indicated (and was confirmed during this test) that the shaker manufacturer's published limits for armature lateral loading would be greatly exceeded unless the input to the test item was reduced at certain frequencies. The sine sweep input was also notched to limit the shaker lateral forces and moments to 1.5 times the manufacturer's limits.

Acoustics

For the acoustics test, the satellite was instrumented with 108 accelerometers - the majority of which were common with the sine vibration locations. Several sine test accelerometers were not recorded for this acoustics test and a few new locations were added - primarily internal to the instrument module at inputs to the sensor electronics assemblies. No strain gages or force washers were recorded for the acoustics test.

RESULTS AND CONSTRAINTS

Sine Vibration

The initial very low level random and the 1/4g sine were performed with all 48 satellite response safety aborts set at their original 100% level. The principal objective of this was to obtain the data from a complete, unbroken sine input across the test frequency range of 5 to 100Hz.

For the intermediate (3/4g) level sine sweep, the 48 peak limit abort thresholds were set proportional to the full level limits (although not exactly 50%) and the first cut notching, scaled from the expected full level sine, was implemented. The intermediate level sine sweep had seven peak limit aborts. This necessitated the increase of abort limit levels and/or lowering of the limiter low pass filter settings on the affected locations from 200Hz to 100Hz. The input sine profile was not changed.

For the full, protoflight, level sine sweep, the 48 peak limit abort thresholds were set as previously described. These abort values were ≈10% above the desired limit levels to allow for overshoot, etc. All limit low pass filters were set at 100Hz. The sine profile for this run was modified slightly from the 3/4g level based on the data from that run. The profile is shown in Figure 3 along with the respective notch determining locations along the frequency band. The sine vibration input to the LVA satisfied an Arianespace request that it envelope 1.5 times the shock spectrum, divided by Q, of the predicted launch vehicle transient events. This is also shown in Figure 3. There were no peak limit aborts during the PF sine sweep.

The very low level random vibration was repeated immediately upon conclusion of the PF sine run for the purpose of comparing before and after sine response characteristics and assessing structural integrity. No significant changes were revealed.

Acoustics

The revised, Ariane-4 acoustic noise spectrum was applied to the satellite in three steps up to and including full protoflight as previously described. A primary concern centered around predicted random vibration input levels to some assemblies that would exceed their qualification/acceptance test inputs at the frequencies where the new acoustic spec was increased - principally in the 100Hz to 250Hz range. This situation did, in fact, present itself based on the -12dB data for the input to the Global Positioning System receivers on the Instrument Module +Y access panel. Extrapolation of the -12dB data indicated that the PSD level at ≈140Hz would reach $0.8g^2/Hz$ at full level as compared to the assembly test level of $0.2g^2/Hz$ at that frequency. Three additional accelerometers were added to the outside of this access panel before going to the -6dB level to confirm the reading and to determine whether or not the high response was the result of some localized effect.

The -6dB acoustic run data verified that the GPS receiver input reading was correct and not just a localized phenomenon. However, the increase in the vibration response was less than the 6dB increase in the acoustic level - actually closer to 4dB. Based on this result, anticipation of a similar increase at full level and consultation with the GPS cognizant engineers, it was decided to proceed with the full PF acoustic exposure without modification. A comparison of the responses at the GPS receiver and other electronic box locations on the spacecraft instrument module and bus with the $0.2g^2/Hz$ random vibration test specification is shown in Figure 4.

The PF acoustic run (146dB overall) gave a reading of $0.35g^2/Hz$ at the input to the GPS receivers. Again, this represented an increase of just over 4dB from the -6dB acoustic run. No other assembly level random vibration input levels were exceeded during this test. The only other area of minor concern was at the High Gain Antenna Subsystem mechanism. Even though the response level here was quite high ($3g^2/Hz$ at 160Hz) it was nearly identical to that measured during its assembly random vibration qual. In the acoustics test, this mechanism response is believed to be predominantly driven by the HGAS dish motion, rather than the IM panel.

SUMMARY AND CONCLUSIONS

The sine vibration and acoustics tests on the TOPEX/Poseidon flight satellite are considered to have been successfully accomplished. The formal, stated objectives of the sine test were met. The initial indications of an anomaly in an inertial reference unit were resolved.

The acoustics test was performed to the revised acoustics levels for Ariane-4 without the need to modify the spectrum. The generally lower than anticipated response throughout the satellite is at least partially attributable to its higher than assumed damping. This was initially observed during the sine vibration and resulted in some notching not having to be as deep as pre-test analysis predicted.

In conclusion, the TOPEX/Poseidon flight satellite is considered to have successfully met each of the principal objectives of both the sine vibration and the acoustics environmental tests and has therefore demonstrated, with margin, its ability to survive the Ariane-4 launch dynamics environments.

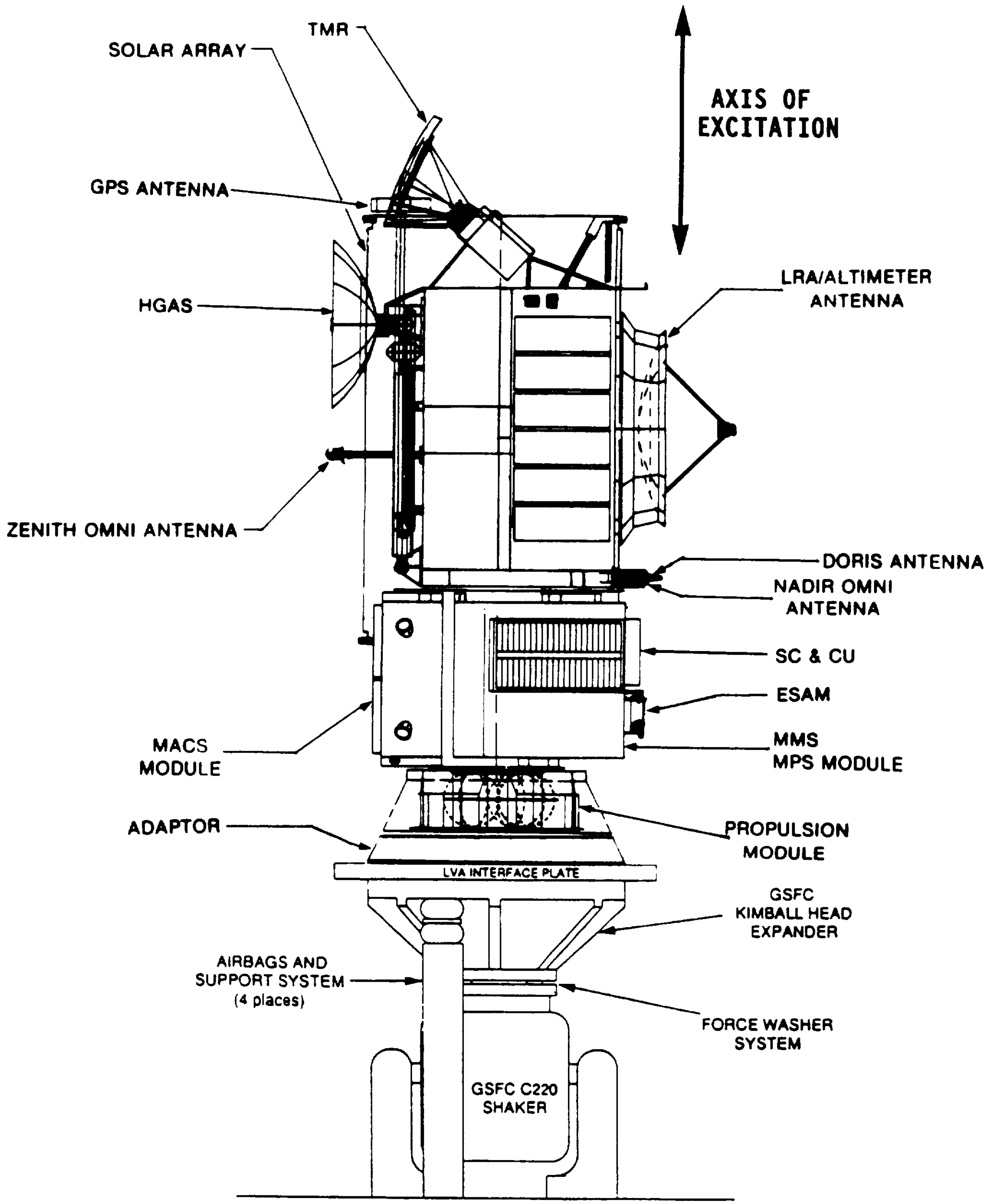


FIGURE 1. TOPEX/POSEIDON SATELLITE SINE TEST CONFIGURATION

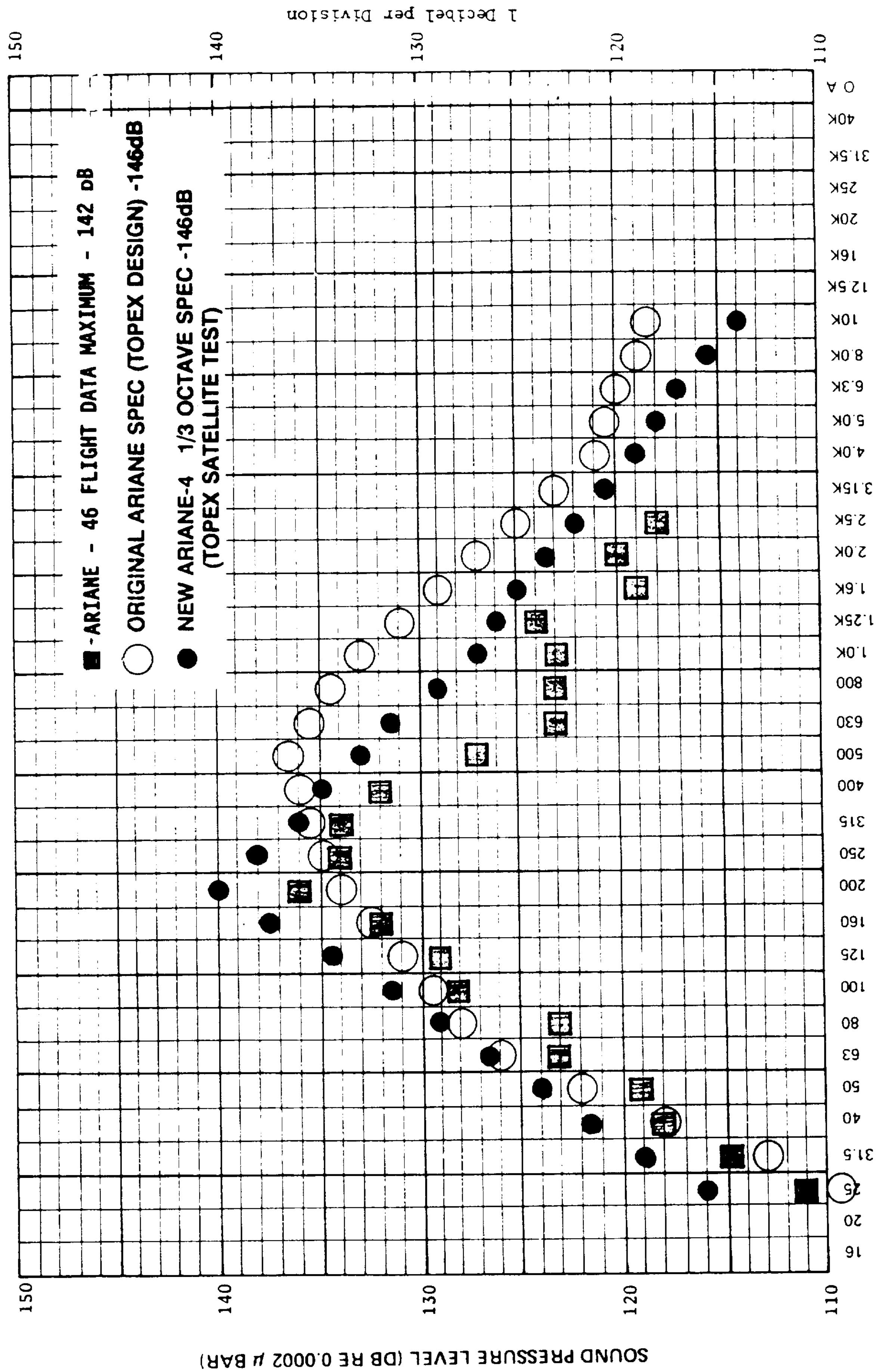
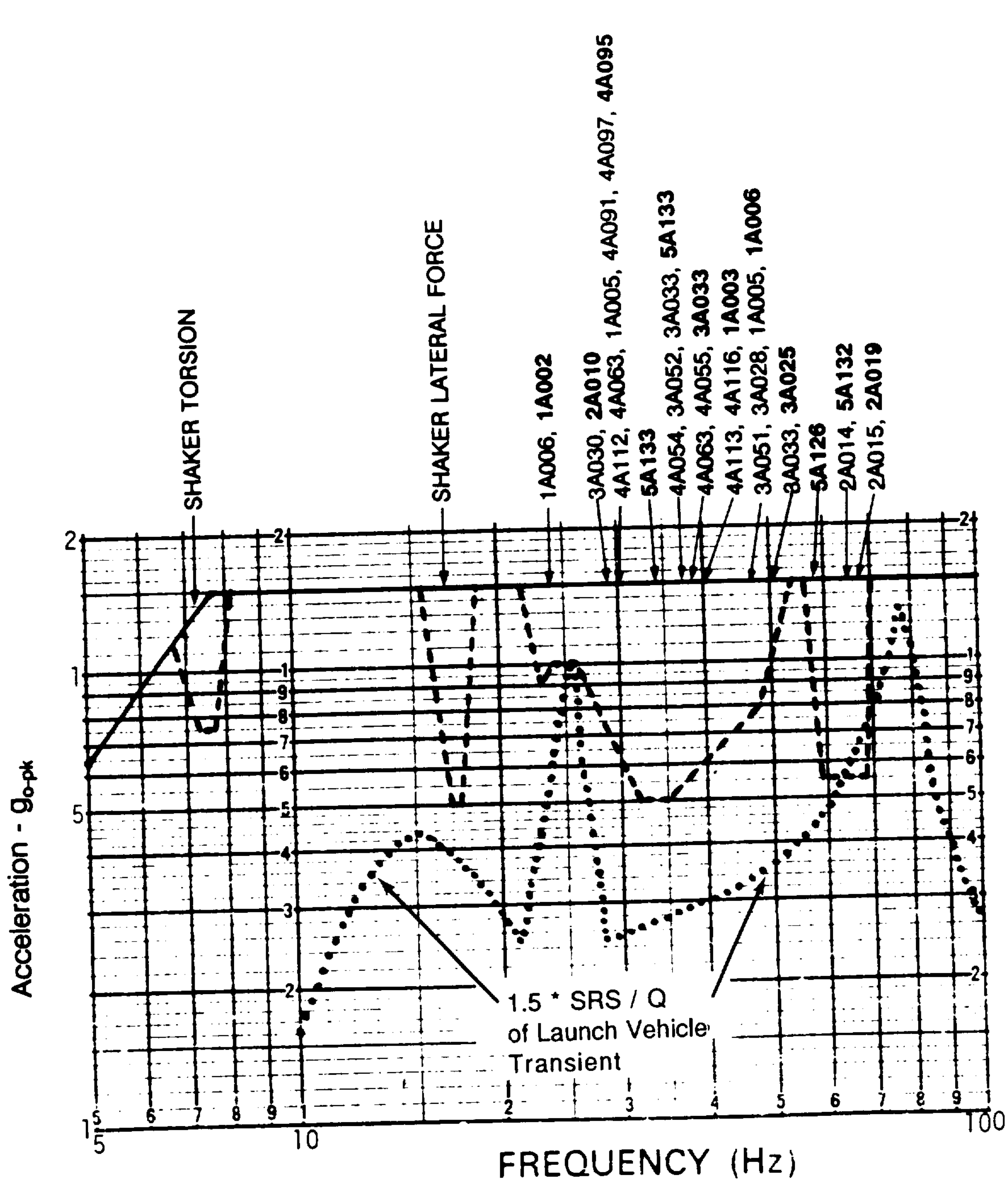


FIGURE 2. TOPEX/POSEIDON FLIGHT AND TEST ACOUSTIC SPECTRA



1A002 - LVA Leg #1; 'Y'
1A003 - LVA Leg #1; 'Z'
1A005 - LVA Leg #2; 'Y'
1A006 - LVA Leg #2; 'Z'
2A010 - Prop. Mod./PME; 'X'
2A014 - ATK Top; 'Y'
2A015 - ATK Top; 'Z'
2A019 - ATK Top; 'Z'
3A025 - C&DH B'plate center; 'W1'

3A028 - MACS Mod/RWA; 'W2'
3A030 - MACS Mod/Opt Bench; 'V2'
3A033 - MACS Mod/ B'plate; 'V2'
3A051 - SCCU/ESAM; 'Y'
3A052 - SCCU/ESAM; 'Z'
4A054 - IM +X, +Y, +Z Corner; 'Y'
4A055 - IM +X, +Y, +Z Corner; 'Z'
4A063 - IM +X, -Y, -Z Corner; 'Y'
4A091 - S/A panel 4 +X, -Z; 'X'

4A095 - S/A panel 4 -X, +Z; 'X'
4A097 - S/A panel 4 -X, +Z; 'Z'
4A112 - S/A truss leg -X, +Z; 'X'
4A113 - S/A truss leg -X, +Z; 'Y'
4A115 - S/A truss leg -X, -Z; 'X'
4A116 - S/A truss leg -X, -Z; 'Y'
5A126 - Alt. Feed Horn; 'X'
5A132 - TMR box; 'X'
5A133 - TMR box; 'Y'

FIGURE 3. NOTCHED INPUT IN SATELLITE SYSTEM SINE TEST

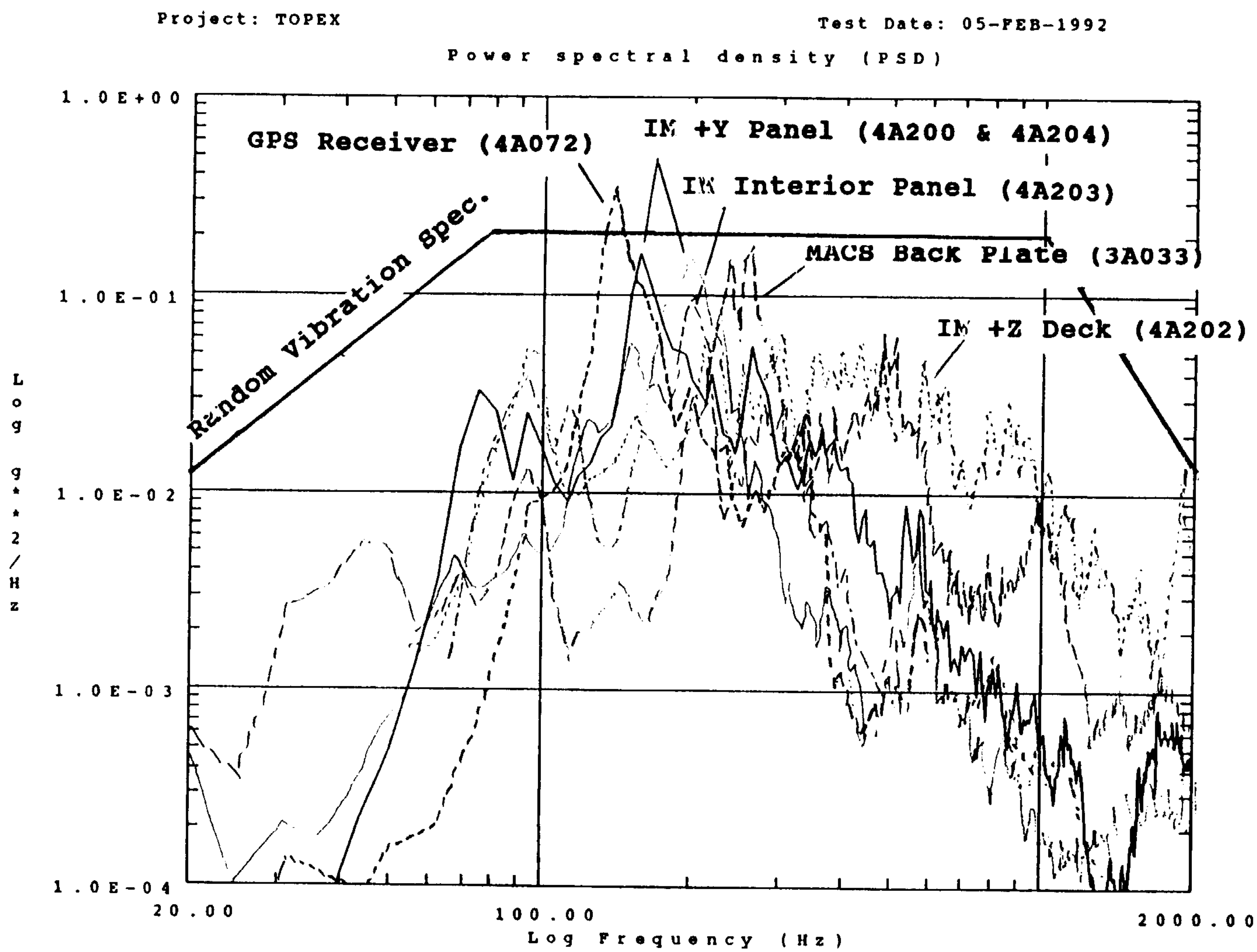


FIGURE 4. COMPARISON OF ELECTRONIC BOX INPUTS IN SYSTEM ACOUSTIC TEST WITH BOX RANDOM VIBRATION TEST SPECIFICATION