NON CONFORMANCES LIST

SEQ. N°	NCR IDENTIFICATION NUMBER	DESCRIPTION/TITLE	Major(M) Minor(m)	ISSUE - DATE		RFW REF.IDENTIFICATION	ORIGINATOR	CLOSE OUT DATE	REMARKS
1	NCR-RICSYS-CGS-C-001	Dimension missing p/n: 12-RICSYS-10.001 s/n:N.A.	m	1	21/06/04	N.A.	CGS	27/11/06	
2	NCR-RICSYS-CGS-C-004	RICH FM structure NDI method p/n: 12-RICSYS-20.000 s/n: N.A. p/n: 12-RICSYS-30.000 s/n: N.A.	m	1	29/06/04	N.A.	CGS	14/07/04	
3	NCR-RICSYS-CGS-C-005	RICH FM Reflector Dimensional Measurement p/n: 12-RICSYS-50.002 s/n: N.A	m	1	12/10/04	N.A.	CGS	14/10/04	
4	NCR-RICSYS-CGS-C-006	RICH beams rework due to magnet test p/n: 12-RICSYS-20.001 s/n: N.A. p/n: 12-RICSYS-30.001 s/n: N.A. p/n: 12-RICSYS-30.003 s/n: N.A.	m	1	28/01/05	N.A.	CGS	20/04/05	
5	NCR-RICSYS-CGS-C-007	RICH Primary Beam drawing update p/n: 13-RICSYS-00.001 s/n: N.A.	m	1	28/01/05	N.A.	CGS	08/03/05	
6	NCR-RICSYS-CGS-C-008	RICH Linerar EXTERNAL Y drawing update p/n: 13-RICSYS-00.006 s/n: N.A.	m	1	08/02/05	N.A.	CGS	08/03/05	
7	NCR-RICSYS-CGS-C-009	RICH Linerar EXTERNAL X drawing update p/n: 13-RICSYS-00.005 s/n: N.A.	m	1	08/02/05	N.A.	CGS	08/03/05	
8	NCR-RICSYS-CGS-C-014	Rich FM Reflector Reflectivity p/n: 12-RICSYS-40.000 s/n:01	m	1	29/09/05	N.A.	CGS	20/10/06	
9	NCR-RICSYS-CGS-C-020	RICH FM Vibration Test	M	3	03/12/07	N.A.	CGS	03/03/08	

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CARLO GAVAZZI SPACE SpA

RICH System

NON CONFORMANCE REPORT

NCR ref

Doc.Nº: NCR-RICHSYS-CGS-C-020
Rev.: 3 Date: 03.12.2007
Page 1 of 3 attach: Annex-A,B,C

2 NCR Title: RICH FM Vibration test

IDENTIFICATION

3 Supplier	4 Purchase Order Nº.	5 Model	6 Subsystem	7 Procedure/Work Item Nº
CGS		FM		

8 NC ITEM Identification	9 Drawing Nº. Rev.	10 P.N. / C.I. Nº	11 Serial Nº
RICH FM	10-RICSYS-00.000	10-RICSYS-00.000 / RICH – FM01	FM 01
12 Next Higher Unit Id.	**13 Drawing Nº. Rev.**	**14 P.N. / C.I. Nº**	**15 Serial Nº.**
N.A.	N.A.	N.A.	N.A.

DESCRIPTION

16 NON CONFORMANCE Detected During:

RECEIVING INSP. [ ] MANUFACT. [ ] ASSEMBLY/INTEGRATION [ ] FINAL INSPECTION [ ] TEST [X] OTHER....see above..... [ ]

17 Initiator, Dept., Date, Signature A. Bursi 19/10/2007 Bursi

18 Description of NON CONFORMANCE

During the first low level random (- 12 dB) along the z axis (step 4.2.4 of RICSYS-PR-CGS-007 is. 3) of the RICH FM Vibration test , it has been noticed that the response of some unit measurements points of the PMTs grids is higher than predicted.

The test has been stopped

19 Requirements violated

INTERNAL NRB DISPOSITIONS

20 INTERNAL NRB Dispositions:

To investigate the reason of the anomalous response

(see next page)

21 Verifications

22 Suspected cause of NC: HANDLING [ ] TRANSPORTATION [ ] TEST EQUIPMENT [ ] TOOLS [ ] SW [ ] DESIGN [ ] OPERATOR/PROCEDURE ERROR [ ] PART [ ] MATERIAL [ ] PROCESS [ ] TEST [ ] OTHER... [ ]

23 Classification MINOR [ ] MAJOR [X]

24 Corrective/Preventive Actions:

25 REQUEST FOR WAIVER YES [ ] NO [X] Nº

26 Analysis Required YES [ ] NO [X] Nº

27 Other related documents:

Department:	28 P.A.	29 Syst. Engineering	30 Program Manager	30	31 C.C.
Name:	L. Cremonesi	M. Molina	M. Olivier		C. Cinquepalmi
Signature:	L. Cremonesi	Molina	M. Olivier		C. Cinquepalmi
Date:	03.12.07	3/12/2007	03/12/2007		03.12.07

CUSTOMER/HIGHER LEVEL CONTRACTOR NRB DISPOSITIONS

32 CUSTOMER/HIGHER LEVEL CONTRACTOR NRB Dispositions (Class Major Only):

21 Verifications

33 Finally determined Cause of NC

34 Corrective/Preventive Actions:

-Analisys (in annex A)
-PVS generation to trace additional activities with respect to approved procedure
-Z axis TEST resume.

35 Customer/HLContractor Approval:

Department:	ASI – PA	ASI - PM			CGS PA/QA
Name:	R. CARPENTIERO	E. Russo			L. CREMONESI
Signature:	R. Carpentiero	E. Russo			L. Cremonesi
Date:	12/02/08	29/2/08			03.03.2008

36 CLOSE OUT CERTIFICATION

PA/QA Stamp: CQ 5 C. G. S.

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37 CONTINUATION SHEET

☐ SUSPECTED CAUSE OF NC	☒ INTERNAL NRB DISPOSITION	☐ DESCRIPTION OF NC	21 Verifications
☐ FINALLY DETECTED CAUSE	☐ CUSTOMER NRB DISPOSITION	☐ CORRECT/PREVENT. ACTIONS	
☐ REQUIREMENTS VIOLATED			

INTRODUCTION

After the first resonance search in the Z direction an higher amplification than the predicted one has been detected for the modes at 100 Hz and between 200-500 Hz. In particular the frequencies were the same of the predictions, while the structure amplification was higher. **(See annex A chp 3)** In order to evaluate the structure behaviour under random excitation and to preserve the PMT functionality a low level random at -12 dB and -9dB notched was performed to obtain more information on the g_{rms} response. **(See annex A chp 4-5)**

This second test confirmed the -12 dB low level random vibration test results, no non-linearity effects have been detected. The performed test confirmed an extrapolated PMT lower skin response at 0dB of 24 g_{rms}, that was too high if compared to the procedure limit of the lower skin of 11.3 $g_{rms\,e}$, based on the correlation of RICH FEM model with the single grid test results.

For this reason the test has been stopped and this NCR issued in order to perform additional investigation to evaluate the causes and the corrective actions.

The test session has been concluded with a resonance search to guarantee that during the Z direction vibration test no structural yielding or failure occurred up to now **(See annex A chp 6)**

PERFORMED NCR INVESTIGATION

1. After the test session conclusion additional investigations have been immediately addressed to evaluate possible concurrence of the expander modes on the excitation level, taking advantage of the facility availability. Some additional resonance search runs have been performed monitoring all the interfaces to the shaker **(See annex A chp 7)**.

1. The obtained result was that the expander showed three amplifications at the following frequencies:

- F1=222.74 Hz;
- F2=325 Hz;
- F3=528 Hz.

A RICH main mode frequency is 209 Hz, therefore the detector and the expander had a modal coupling that increased the amplifications over 200 Hz.

In order to confirm this assumption and limit the over-excitation a different control setup is proposed, not to change the expander hardware.

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37 **CONTINUATION SHEET**

☐ SUSPECTED CAUSE OF NC ☒ INTERNAL NRB DISPOSITION ☒ DESCRIPTION OF NC
☐ FINALLY DETECTED CAUSE ☐ CUSTOMER NRB DISPOSITION ☐ CORRECT/PREVENT. ACTIONS
☐ REQUIREMENTS VIOLATED

2 1 **Verifications**

2. Two additional control accelerometers need to be added to improve the system control performances and an additional RS was performed. **(See annex A chp 8).**

3. Based on the results (actual frequency response) of the new control setup, a analytical prediction of the full MEFL level output for Z direction vibration is calculated. **(See annex A chp 9)**

4. The further investigation carried out by CGS is to evaluate the effect of a notching in the 100 Hz frequency range to match the limit of 11.3 g_{rms} **(See annex A chp 10).**

5. INFN, as responsible of the RICH mission success, has revised and approved the investigation described so far where the control setup has been modified to improve expander behavior and correlate test results with FEM hard mounted prediction **(See annex A).**

After consulting with NASA it has been further clarified that, based on the behavior of the overall AMS-02 payload, notching of the applicable input spectrum specific to the RICH, corresponding to the 3.2gRMS MEFL(maximum espected flight level applicable to the RICH according to the *JSC-28792* SVP) can be used for the testing **(see ANNEX B).**
Moreover the notched response to the RICH lower skin can be limited to a maximum vibration level of 6.8 g_{rms} (corresponding to the MWL, maximum workmanship level applicable to the RICH according to the *JSC-28792* SVP) **(See annex A chp. 11)**, since, as stated in the document, for electronics components such as the PMTs:
"It is expected that the vibration transmitted through the primary structure to the experiment components will be smaller than Minimum Workmanship Levels (MWL). For mission success it is recommended that vibration testing of the individual electronics components shall be performed to MWL".
Tehrefore the RICH PMTs, will never be subjected to a g_{rms} level higher than 6.8 g_{rms}.
This way the mission success is guaranteed.
An example of the final notching shape is shown in the **annex A chp. 12**
The facility is available for resuming the test from December 10th.

The CGS proposed solution, based on the described results, is to implement the improved control scheme and the notching proposed in investigation step 5.

The test has been successfully repeated on 13.12.2007. See Annex C for the results summary

2. obtained results show that the high amplifications over 200 were due to over-excitation at expander level and the improved control reduces the response to good agreement with the prediction results.The first peak amplification (100 Hz) remained higher than the predicted one.

3. The gRMS are in agreement with the predicted behavior described in the document "RICH SYSTEM RANDOM VIBRATION TEST PREDICTIONS" issue1dr1 of Aug. 2007-10-31. despite the higher amplification of the first mode.

5. The analytical investigation provided a notching figure defined in annex A chp 12

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ANNEX A TO NCR RICHSYS-CGS-C-020 Rev 3

1. REFERENCE DOCUMENTS

RD # (ID)	Doc Number	Issue	Date	Rev	Title
RD 1	RICSYS-TN-CGS-006	1	Aug 2007		RICH SYSTEM RANDOM VIBRATION TEST PREDICTIONS
RD 2	RICSYS-PR-CGS-007	3	20/08/2007		RICH FM VIBRATION TEST PROCEDURE

2. INTRODUCTION

2.1. RICH TEST SETUP Z DIRECTION

The vibration test in Z direction for the RICH system is conducted using a dual shaker system with a 2 m diameter expander, as shown in the following figure.

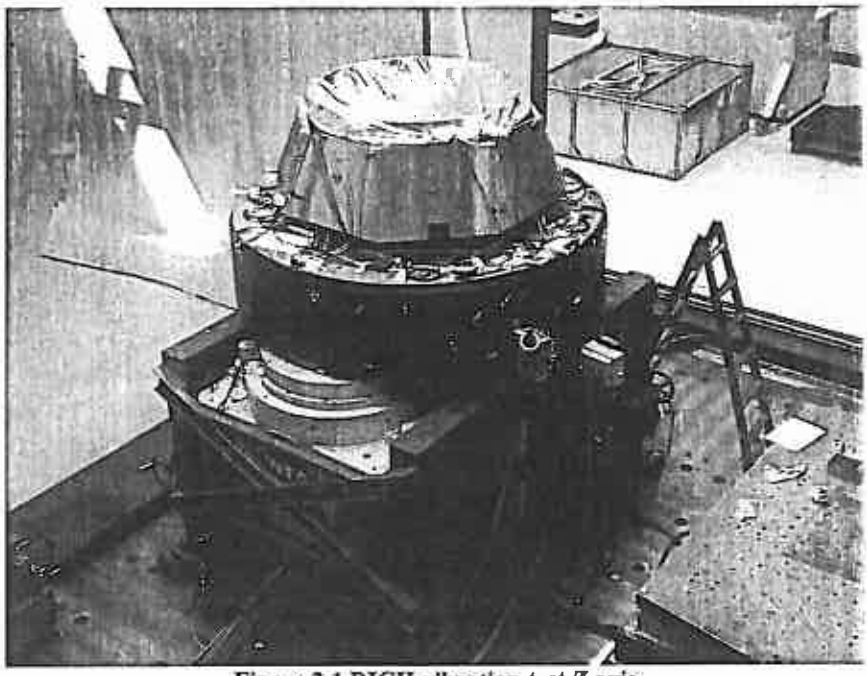

Figure 2-1 RICH vibration test Z axis

To prepare the full level MEFL vibration the following steps have been performed:

- Resonance Search performed by a sine sweep from 5 to 2000 Hz (1 sweep) of 0.3 g constant level for frequency identification.
- Resonance search with a flat 4.3e-5 g^2/Hz (3 g_{rms} level) from 5 to 2000 Hz since the controller was not able to prosecute the frequency sine sweep over 1600 Hz.
- Random Vibration test at MEFL -12dB and -9dB (at notched level) to evaluate amplification and g_{rms} response on the measurement points, reported in the following table

Freq. [Hz]	PSD [g^2/Hz]
20	0.009
45	0.009
125	0.025
300	0.025
900	0.001
2000	0.001

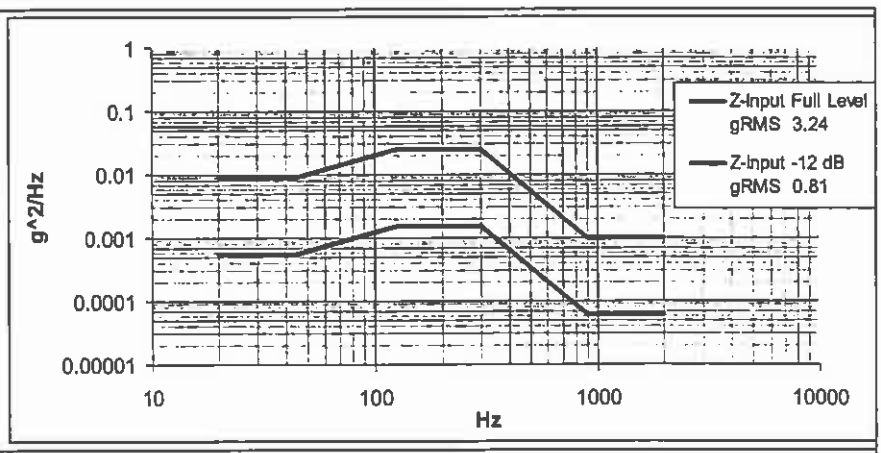

Table 2-1 MEFL Level for the Z direction full level and -12 dB low level

The shaker control system was based on two Control Points (CP) and on the control technique is the maximum. The following figure shows the control accelerometer position on the expander.

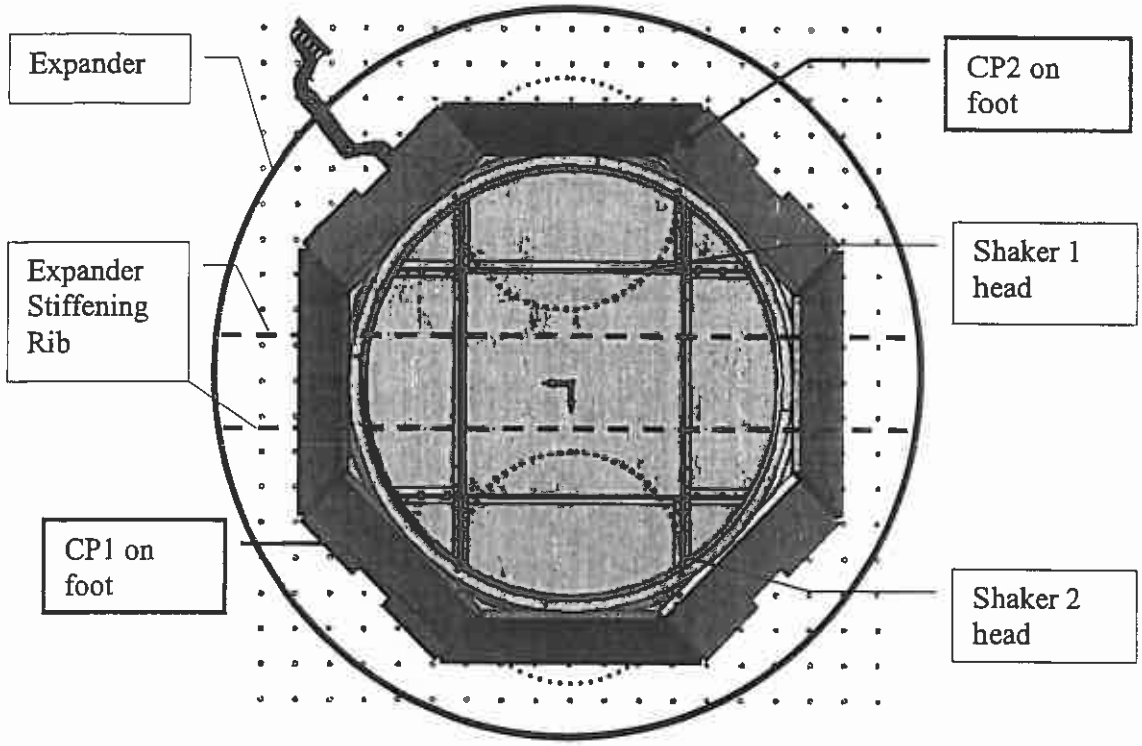

Figure 2-2 Control accelerometer position top view. The CP were placet on RICH supports

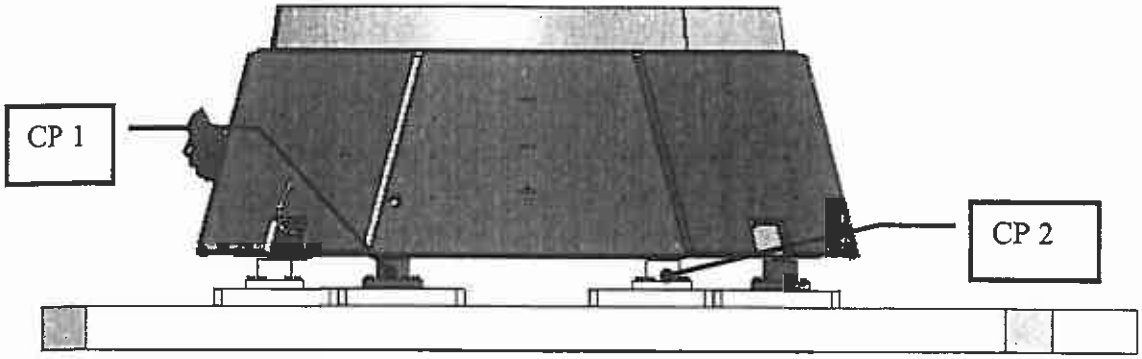

Figure 2-3 Control accelerometer position lateral view.

3. RESONANCE SEARCH RESULTS

After the first resonance search in Z direction (0.3 g 5-2000 Hz) higher response than predicted have been detected on the triaxial accelerometers Acc 1-2-3-4-5-6 points (Figure 3-1) used to monitor the response of the PMT grids.

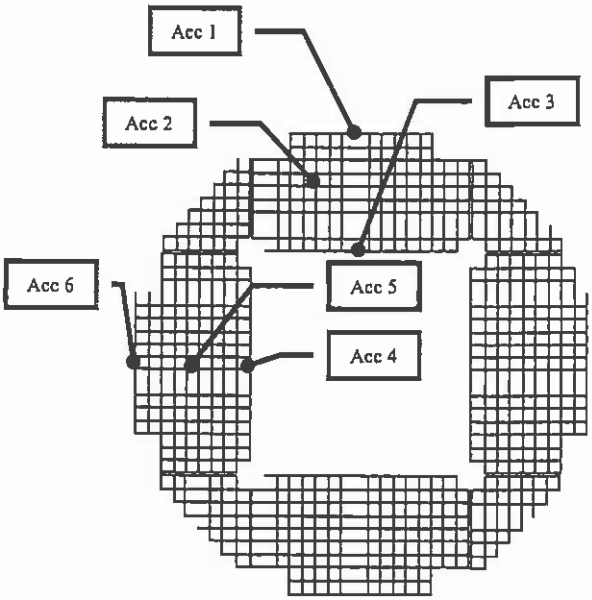

Figure 3-1 Lower Skin points used to monitor the PMT's behaviour

In particular the frequencies were in a good agreement with the predictions [RD1], while the amplifications were higher, for 100 Hz peak and in the range 200-500 Hz.
In the following figures the RS results in Z direction for the lower skin points are shown.

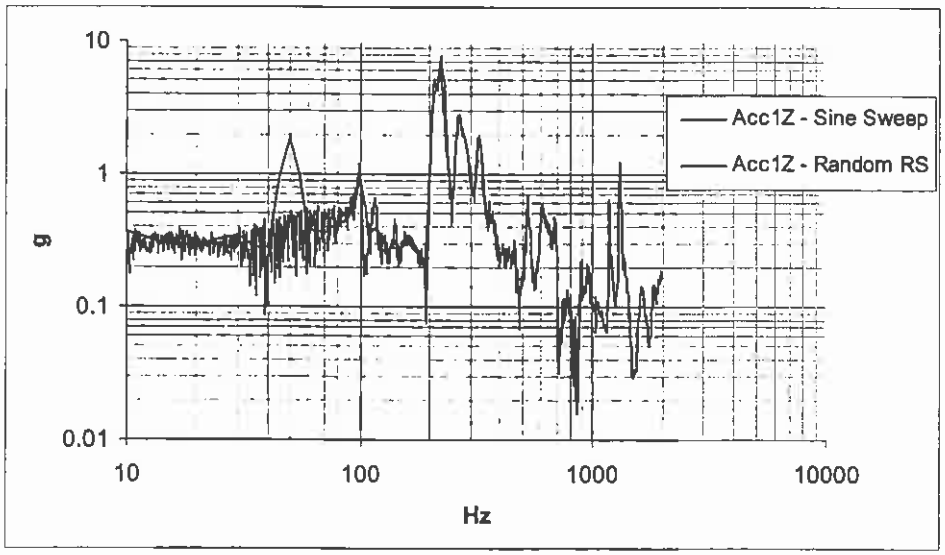

Figure 3-2 Acc1 Z direction position. Comparison between RS sine and random

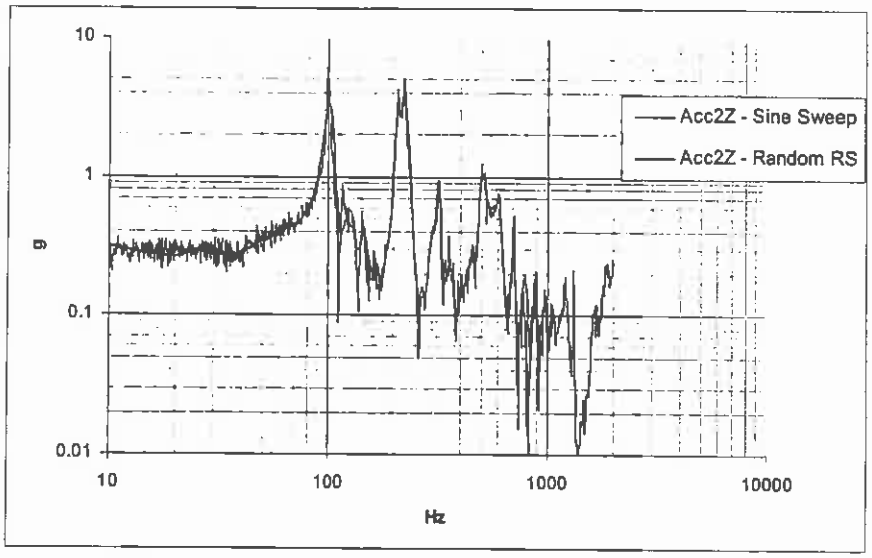

Figure 3-3 Acc2 Z direction position. Comparison between RS sine and random

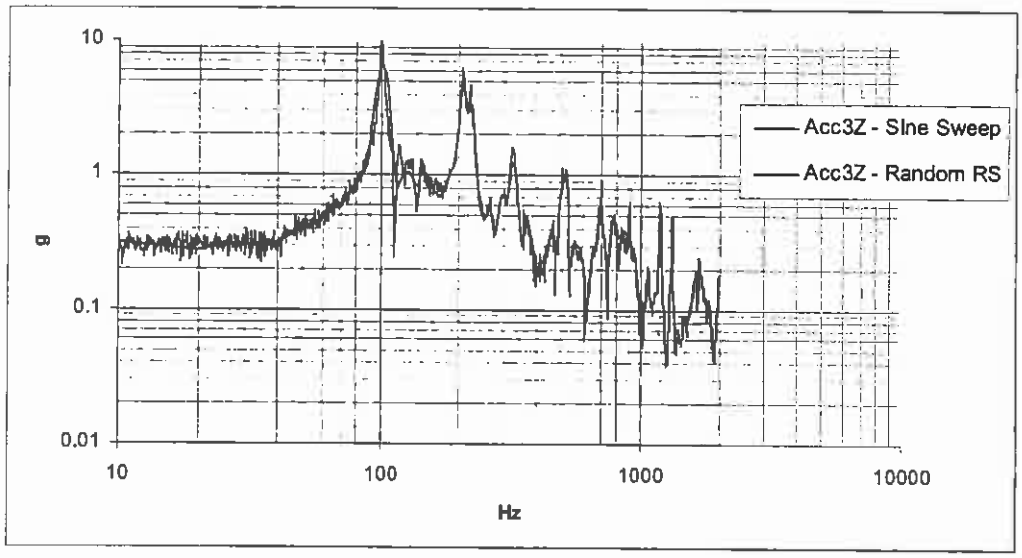

Figure 3-4 Acc3 Z direction position. Comparison between RS sine and random

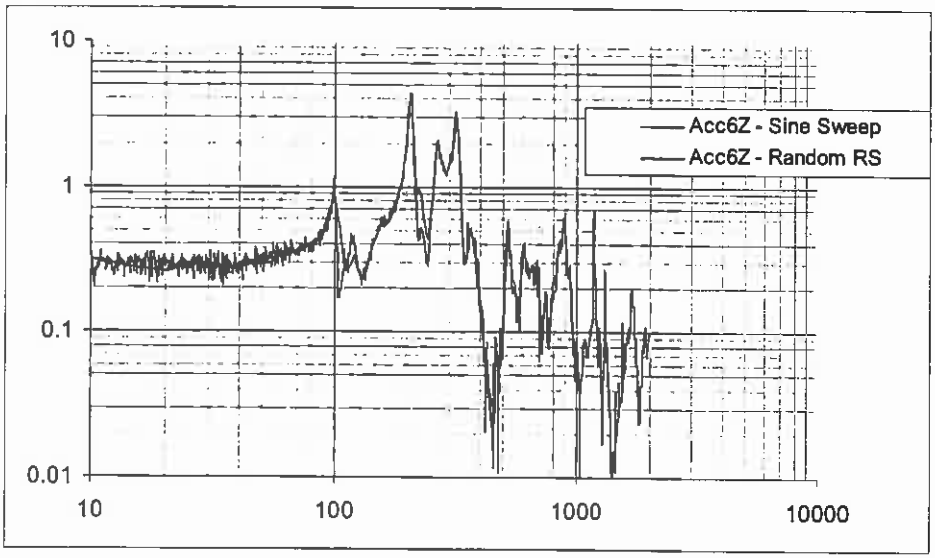

Figure 3-5 Acc6 Z direction position. Comparison between RS sine and random

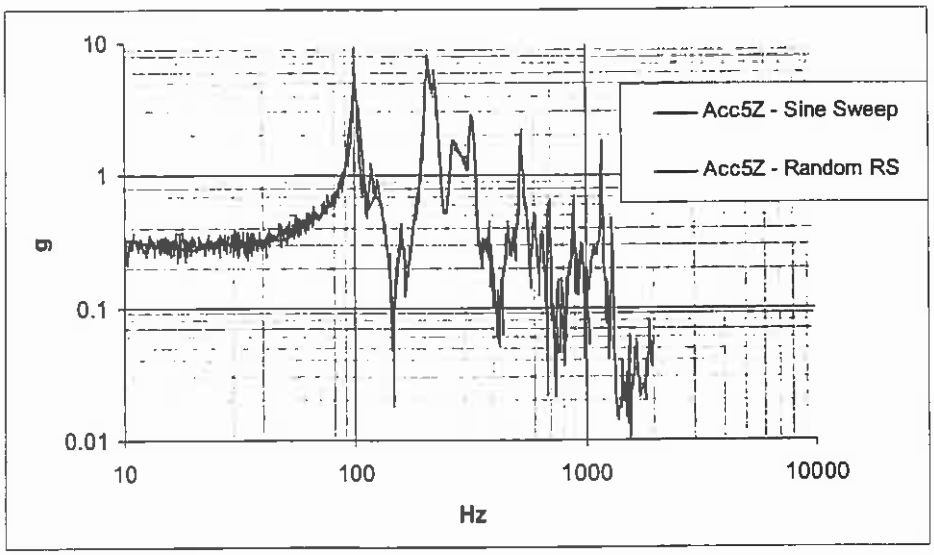

Figure 3-6 Acc5 Z direction position. Comparison between RS sine and random

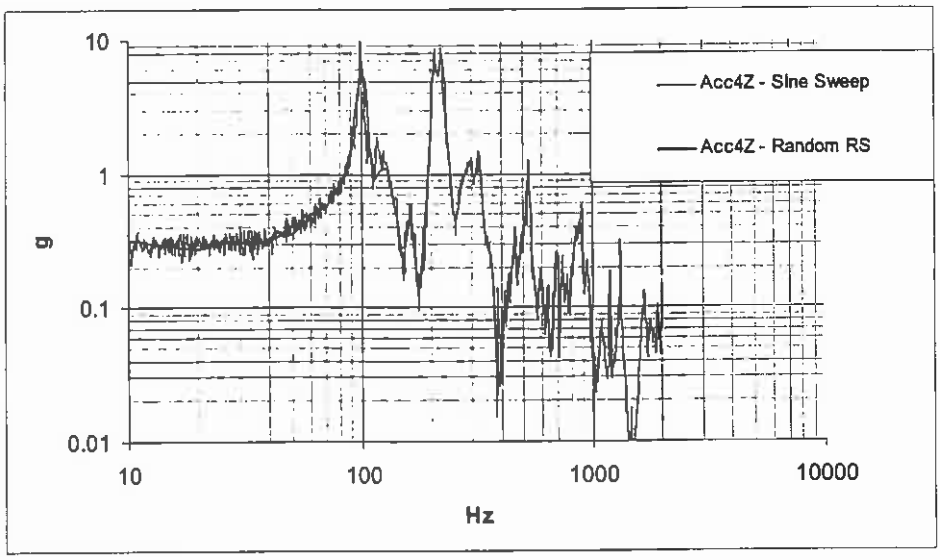

Figure 3-7 Acc4 Z direction position. Comparison between RS sine and random

The RS sine and random were nearly coincident at low frequency (the different frequency steps are responsible of the few discrepancies) and the summation of their contribute allowed to analyze the full frequency spectrum. In the Acc1 output (Figure 3-2) a low frequency (50 Hz) electrical noise is visible; this had no physical relevance.
The following figure show the Acc2 point output FEM prediction and test data comparison; the FEM prediction displayed has been evaluated up to 300 Hz.

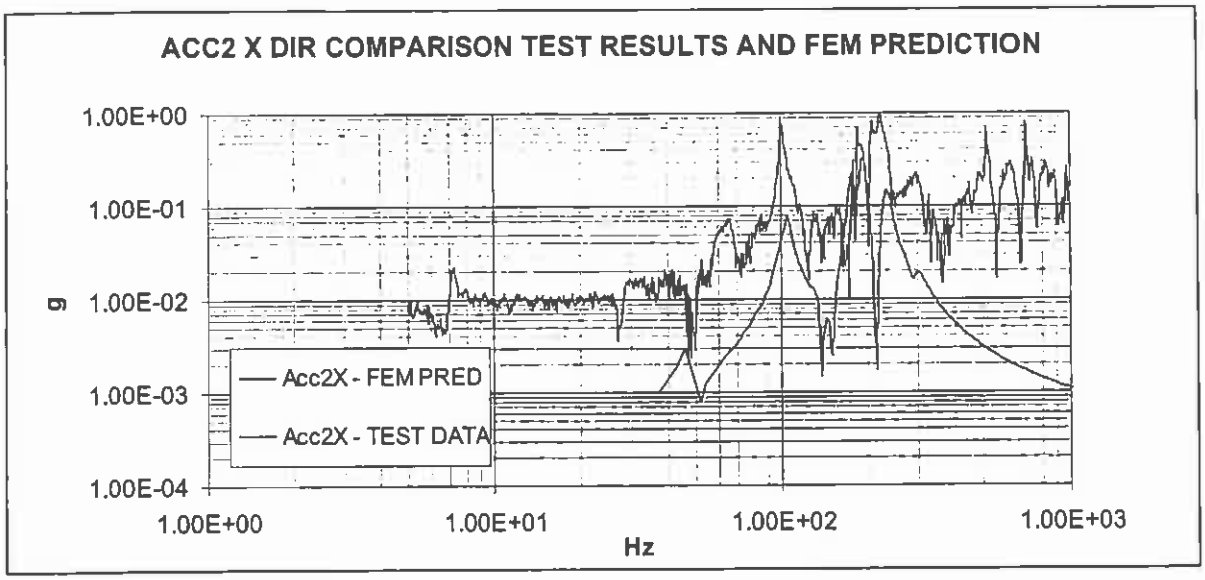

Figure 3-8 Acc2 X direction comparison between RS FEM prediction and test data

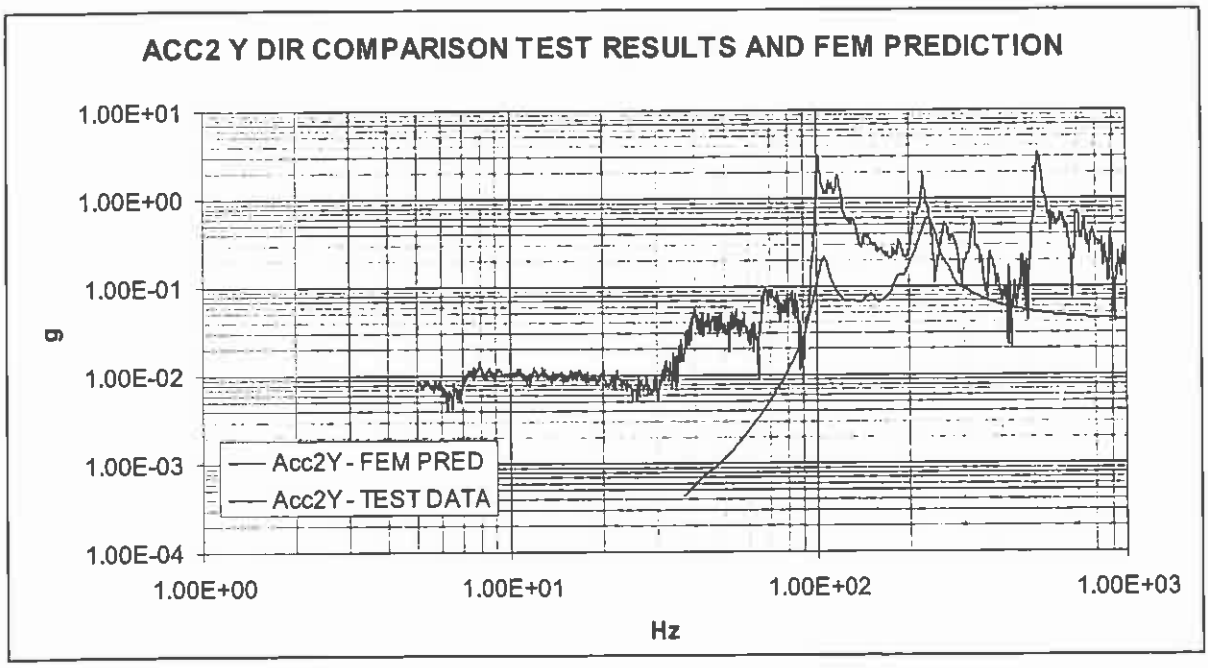

Figure 3-9 Acc2 Y direction comparison between RS FEM prediction and test data

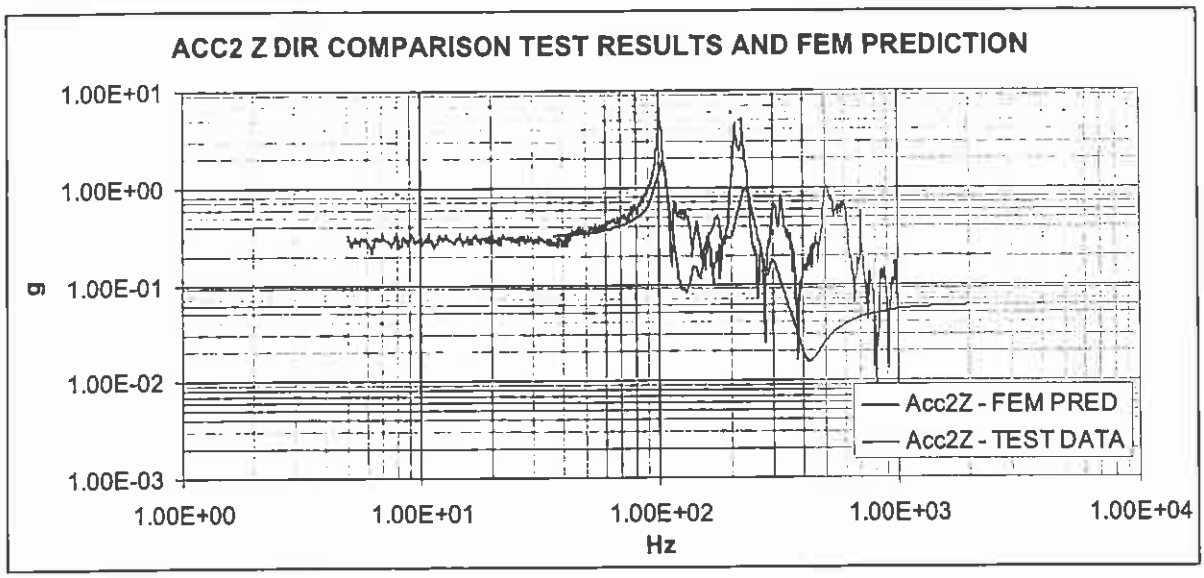

Figure 3-10 Acc2 Z direction comparison between RS FEM prediction and test data

From this results evaluation we have decided to perform the first low level random vibration test (-12 dB) in order to verify the detector amplification with a random input instead of a sine sweep.

4. RANDOM VIBRATION TEST -12 dB

The applied input is reported in the following table.

Freq. [Hz]	PSD [g^2/Hz]
20	0.000563
45	0.000563
125	0.001563
300	0.001563
900	6.25E-05
2000	6.25E-05

Table 4-1 MEFL level Z direction -12 dB

The following figure shows the highest output obtained on PMT grid lower skin in Z direction.

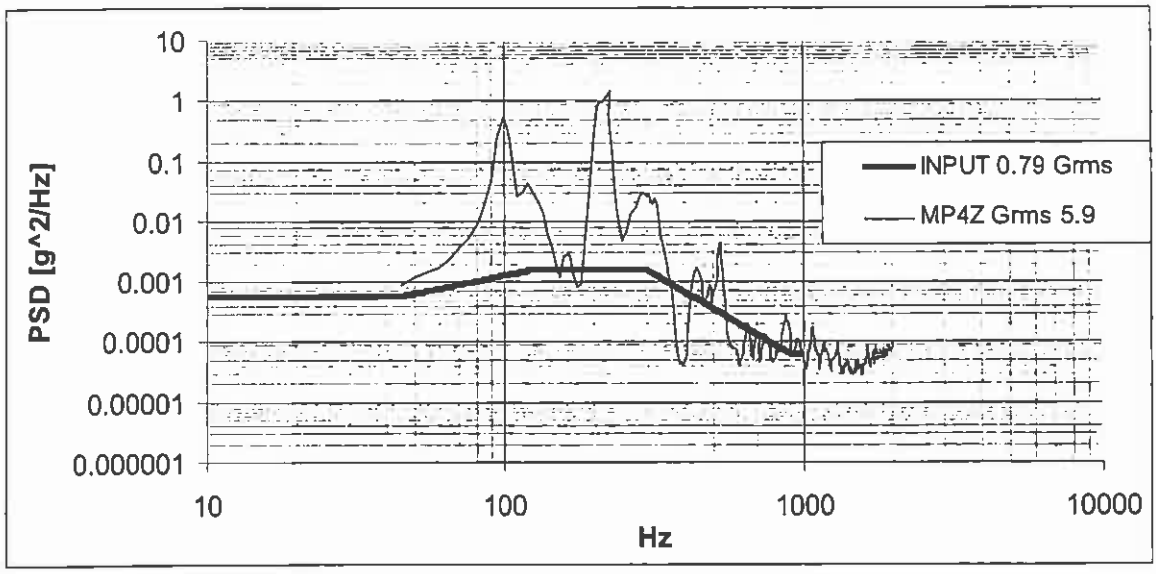

Figure 4-1 Highest Z output for the PMTs monitorino points with -12dB low level random input

The test results showed the same amplification obtained from the sine sweep and confirmed a higher response with respect to the predictions [RD1], in particular the full level acceleration extrapolation from the -12dB results provided 24 g_{rms} on PMT's instead of the predicted 10 g_{rms} of [RD1].
In order to evaluate the PSD linearity a second random low level was performed using a notched -9dB low level.

5. RANDOM VIBRATION TEST -9 dB NOTCHED

The applied input is reported in the following table.

Freq. [Hz]	PSD [g^2/Hz]
20	0.001125
45	0.001125
125	0.003125
150	0.003125
190	0.0008
240	0.0008
270	0.003125
300	0.003125
900	0.000125
2001	0.000125

Table 5-1 Notched MEFL level Z direction -9 dB

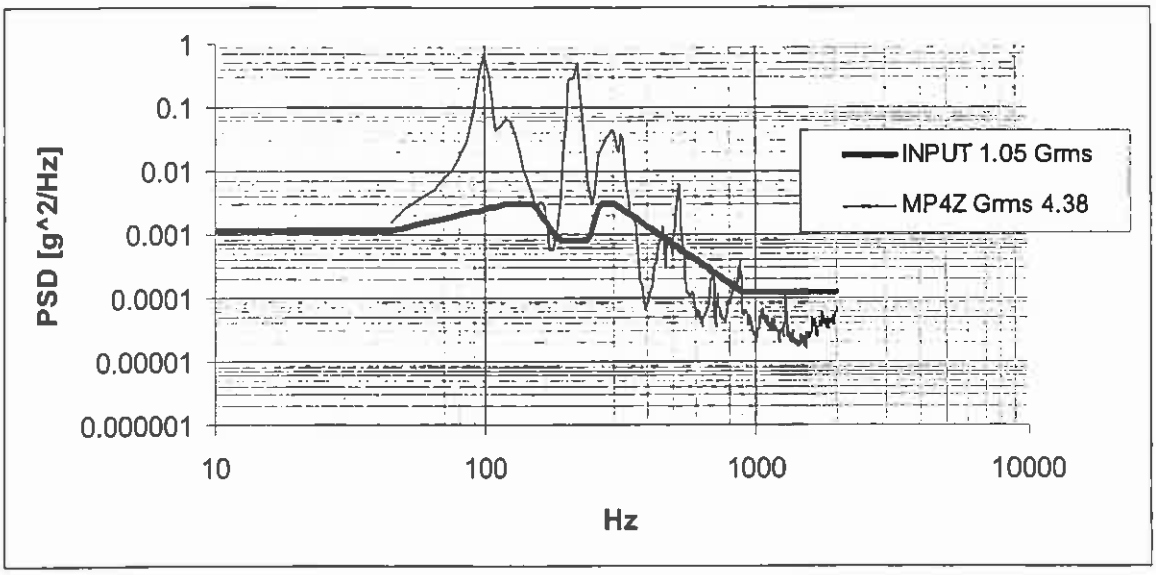

Figure 5-1 Highest Z output for the PMTs monitorino points with -9dB notched low level random input

This second test confirmed the -12 dB low level random vibration test results: no non-linearity effects have been detected on amplification.
A full level extrapolation confirmed the 24 g_{rms} on PMT's monitoring points wrt $10g_{rms}$ predicted, therefore the vibration test has been suspended for investigation on such discrepancy between predicted data and test results.
Before closing the test campaign a RS has been performed to check the detector structural integrity.

6. RESONANCE SEARCH RESULTS

A resonance search in Z direction (0.3 g 5-2000 Hz) has been performed.
No frequency shifts or amplification relevant modification was detected comparing the first and last resonance search of the Z axis runs performed. No structural yielding or failure have been detected.
The following figures show the superimposition of the lower skin accelerometer outputs for the random resonance searches before and after the random vibration test.

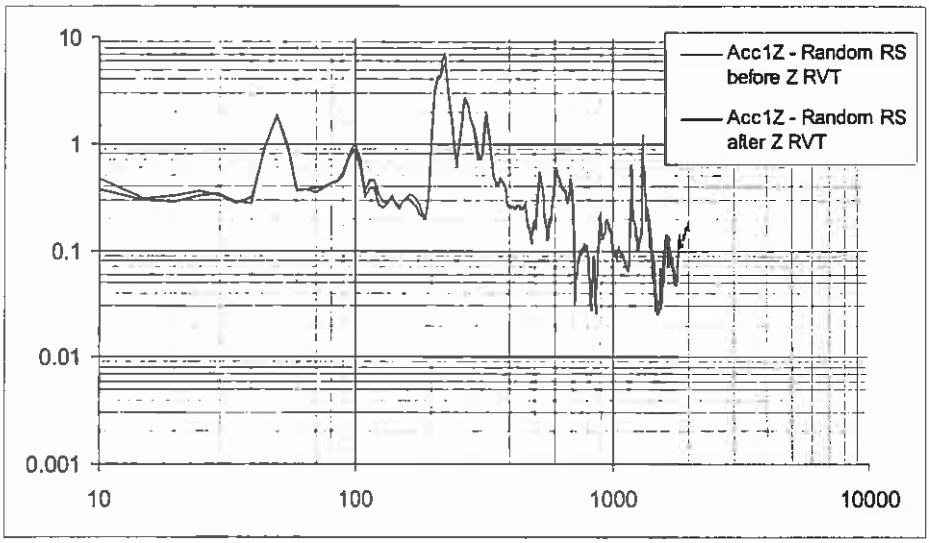

Figure 6-1 Acc1 Z direction position. Comparison between random RS before and after RVT

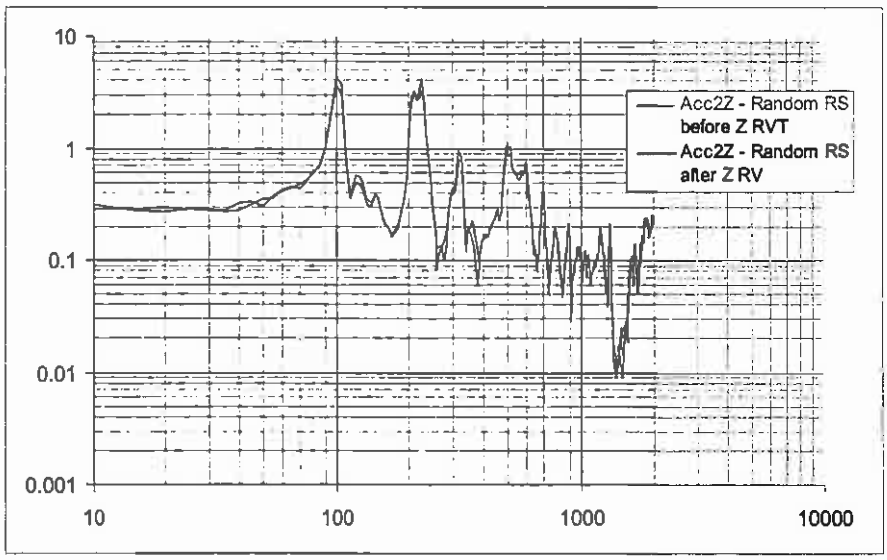

Figure 6-2 Acc2 Z direction position. Comparison between random RS before and after RVT

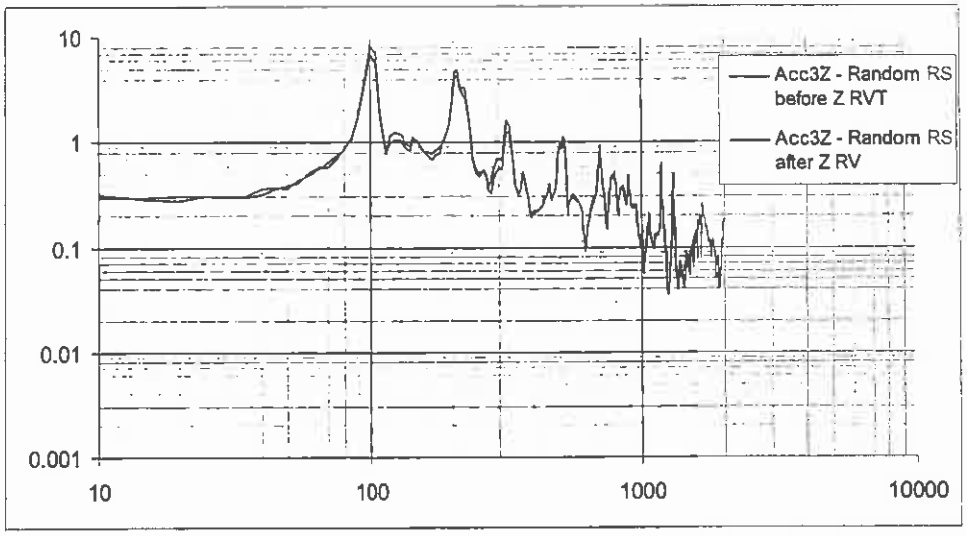

Figure 6-3 Acc3 Z direction position. Comparison between random RS before and after RVT

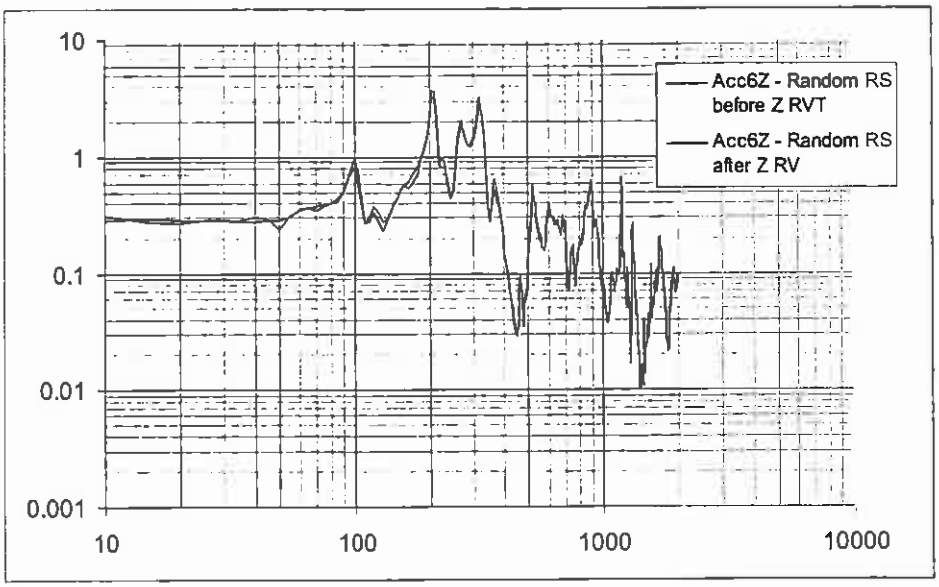

Figure 6-4 Acc6 Z direction position. Comparison between random RS before and after RVT

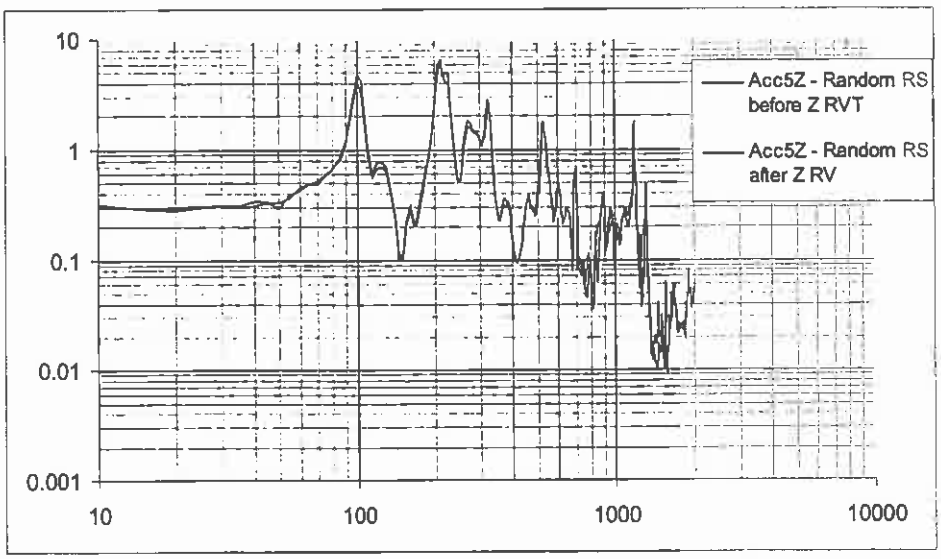

Figure 6-5 Acc5 Z direction position. Comparison between random RS before and after RVT

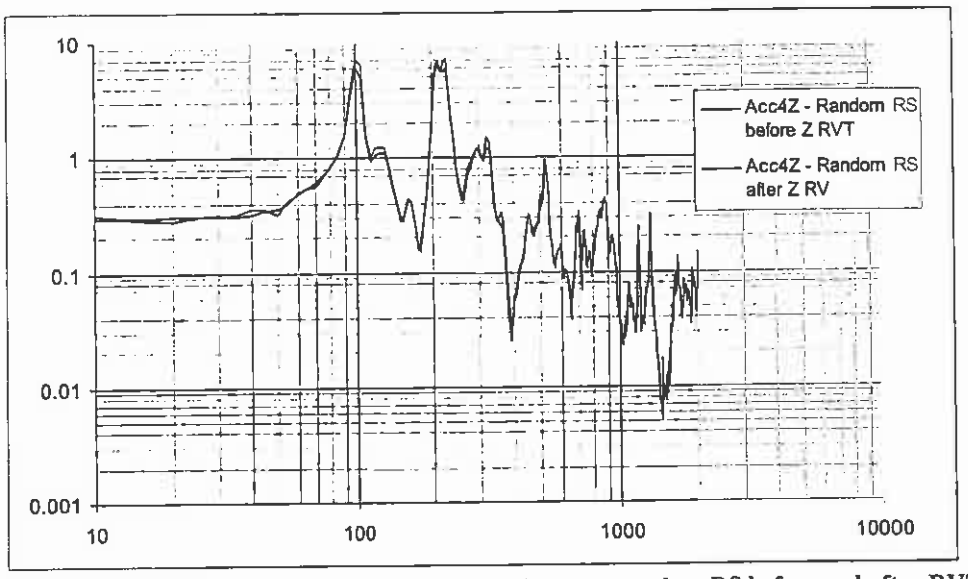

Figure 6-6 Acc4 Z direction position. Comparison between random RS before and after RVT

7. INVESTIGATION ON CONTROL SETUP

In order to evaluate if part of the detected amplification was caused by a non uniform input at shaker expander level, additional resonance searches have been performed monitoring all the eight interface columns of the detector.
The test setup has been maintained, but some accelerometers have been removed from the detector (5 accelerometers from lower skin, two accelerometers from the mirror and 5 accelerometers from debris shields) and placed on the expander, detector supports, and RICH external structure as near as possible to the 8 support interfaces.
The following figures show the accelerometer position for the additional investigations.

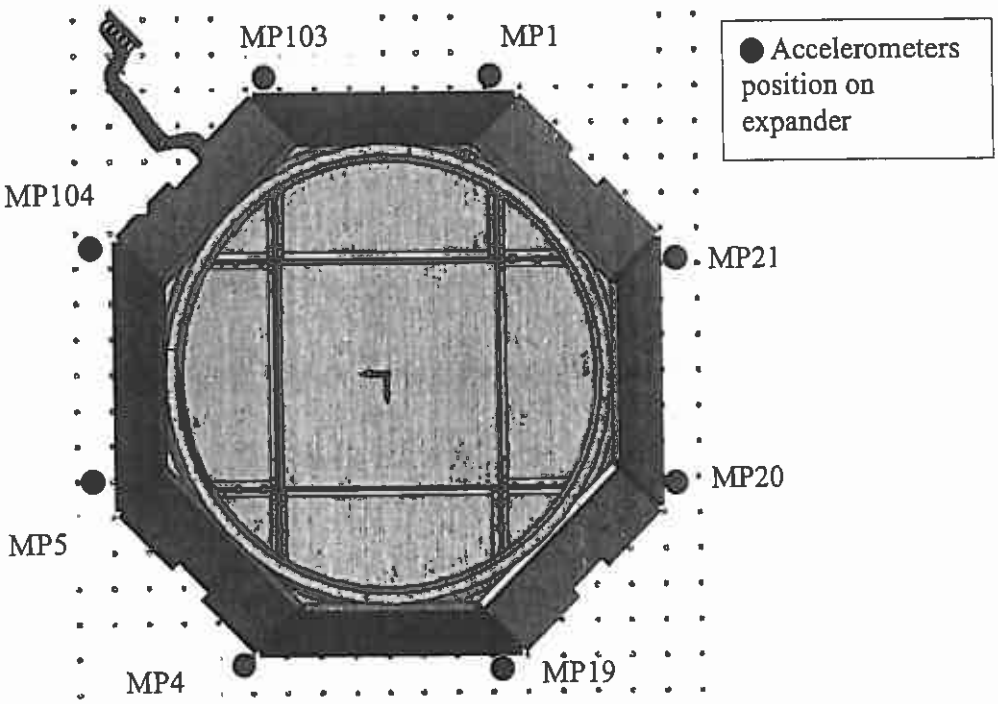

Figure 7-1 Accelerometer position on expander

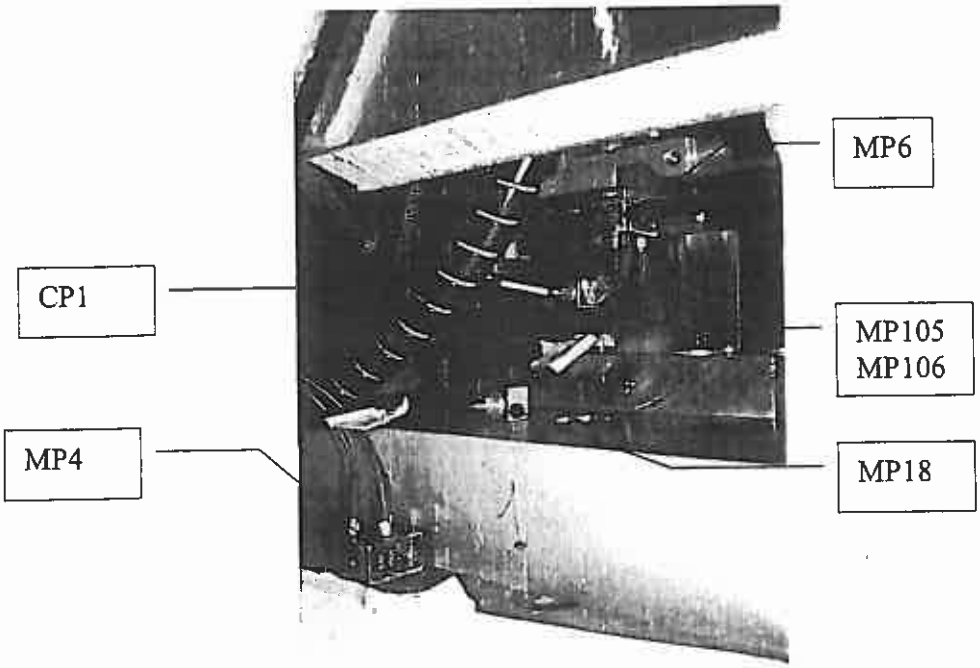

Figure 7-2 Accelerometer position on control 1 foot

Figure 7-3 Accelerometer position on control 2 foot

In the central part of the lower skin of GRID Y and on the external structure the accelerometers have been maintained, as shown in the next figures.

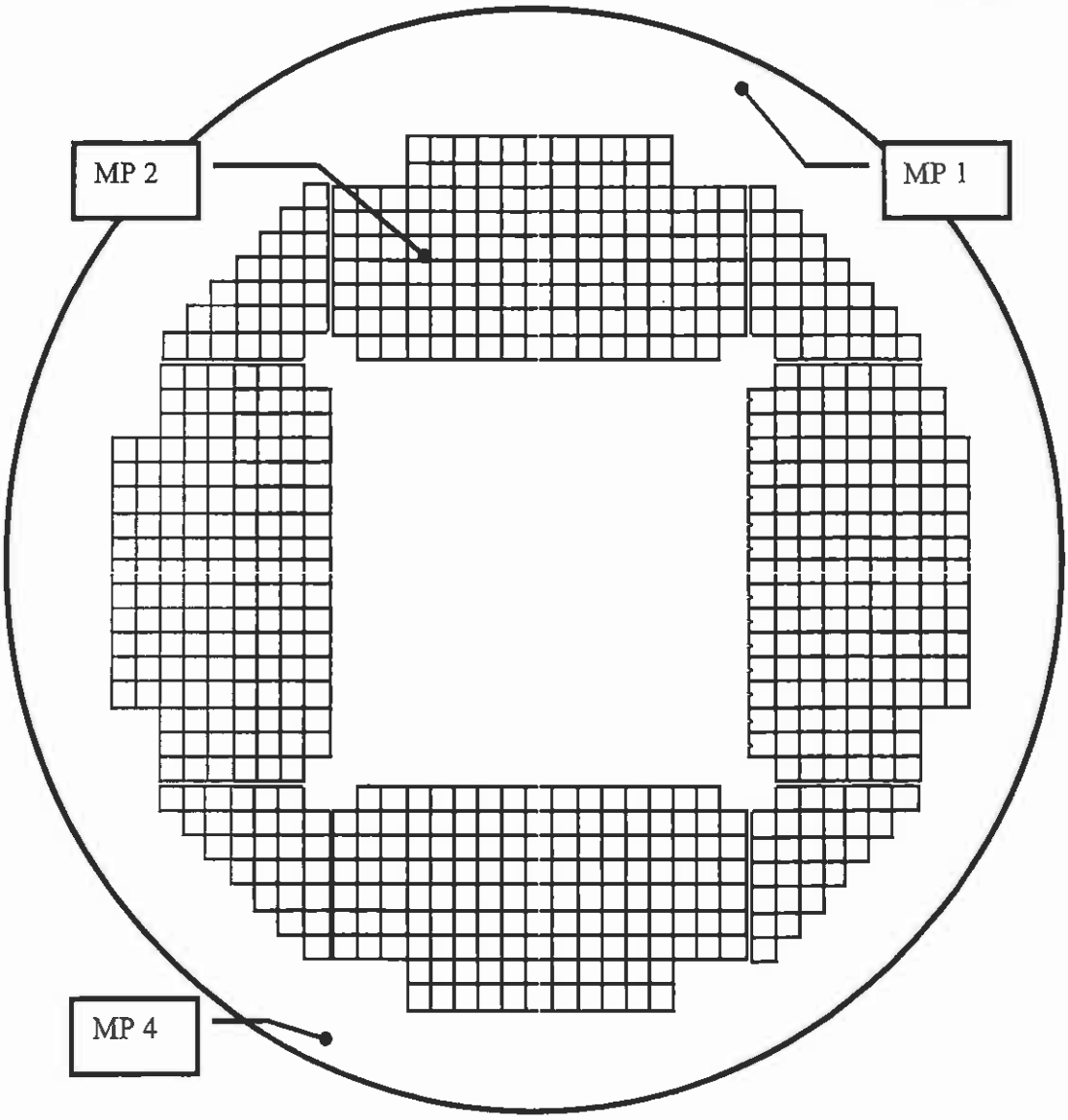

Figure 7-4 Accelerometer position on lower skin; the red line is the shaker expander envelope

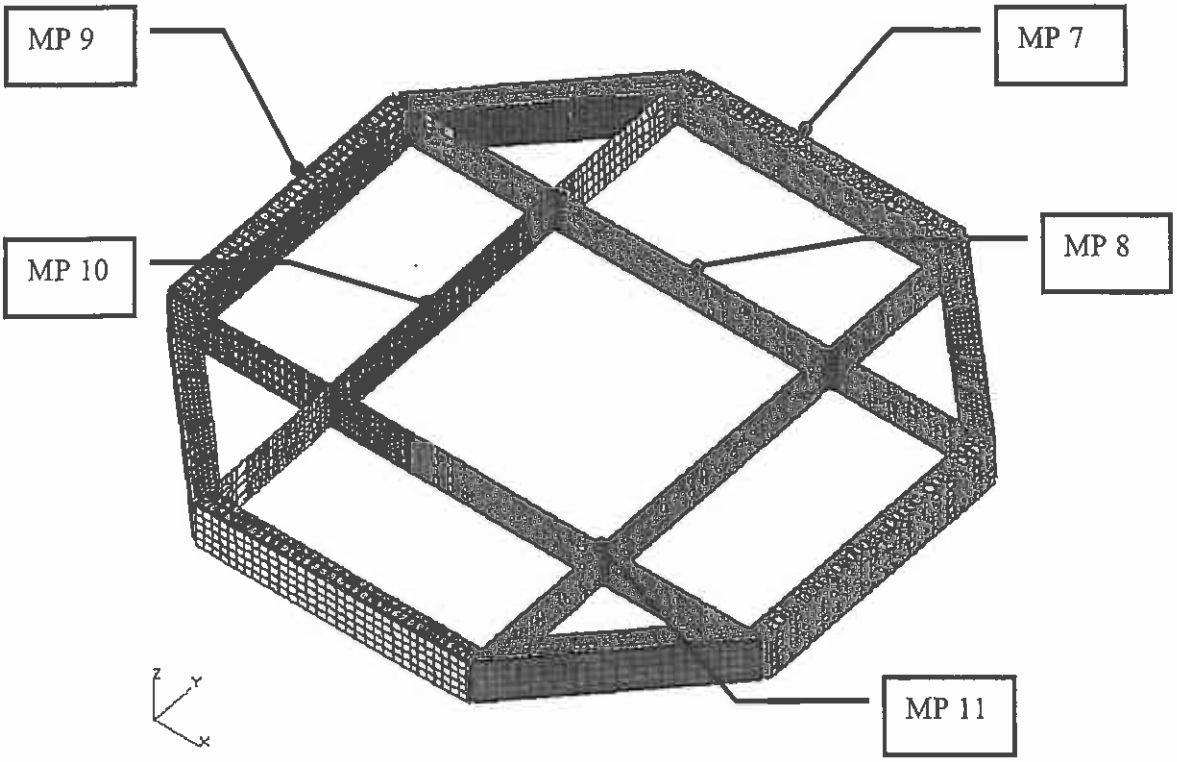

Figure 7-5 External Structure accelerometer positions

Using this measurement points configuration a resonance search from 5 to 1000 Hz was performed to investigate the frequency range of interest.
The following figures show the resulting control and the expander outputs.

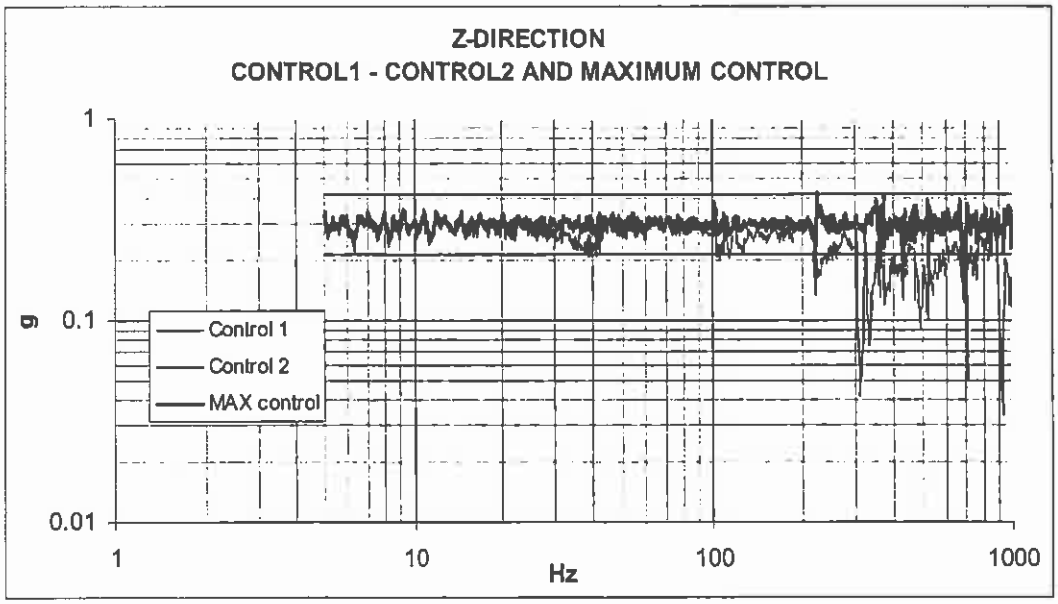

Figure 7-6 Control accelerometers and resulting control signal outputs in Z direction

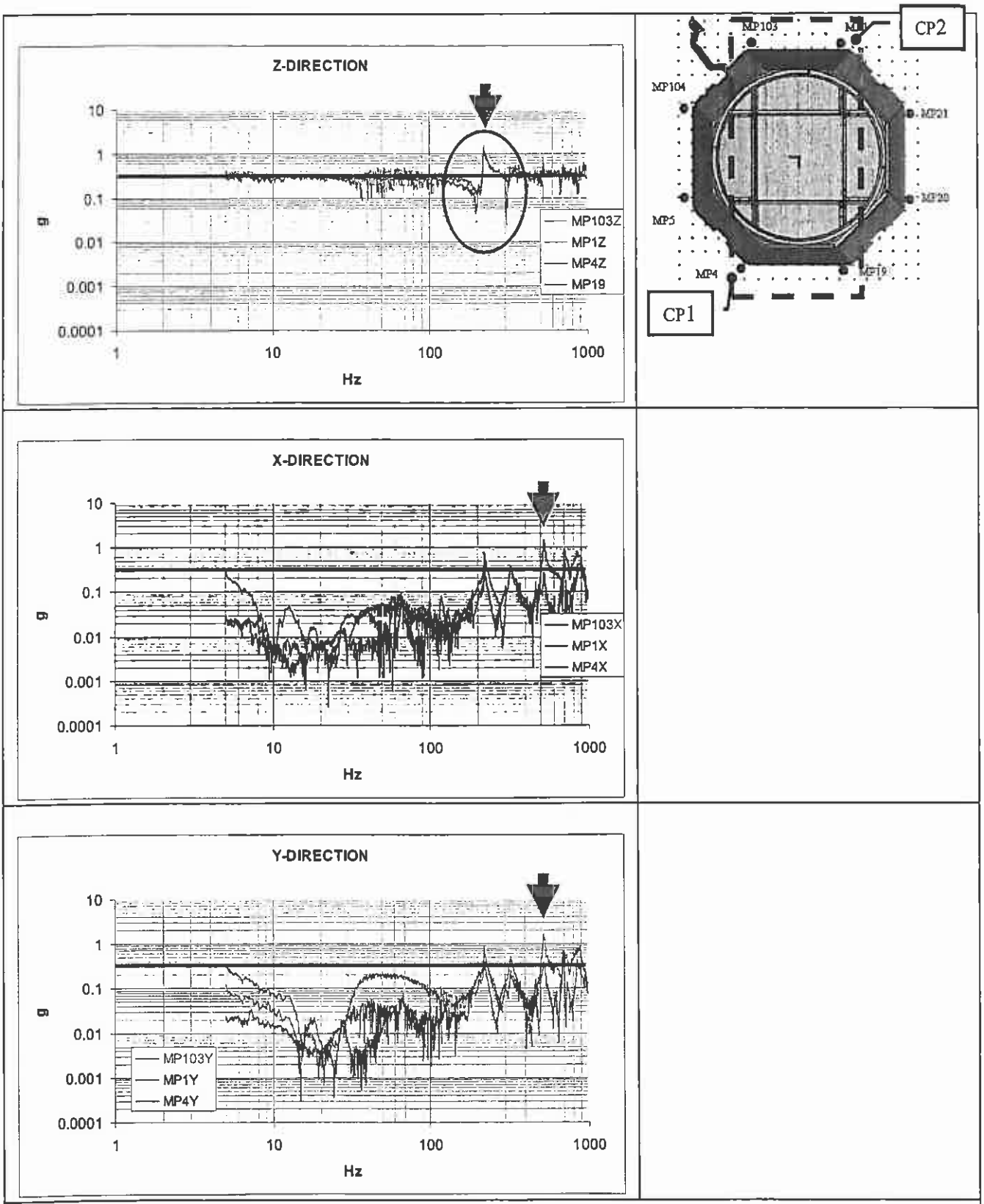

Figure 7-7 XYZ outputs for the expander points near the control points. The arrows show the expander modes.

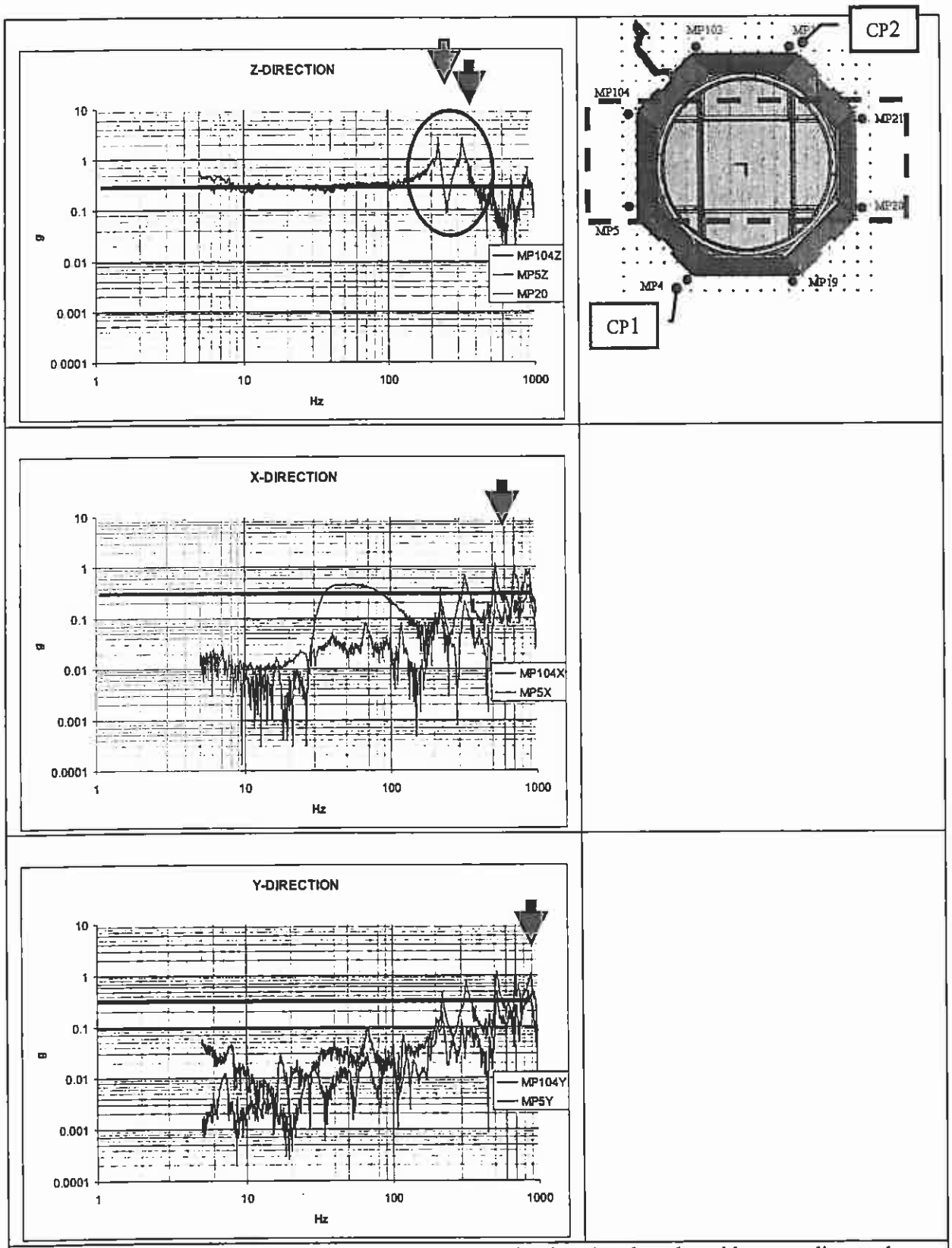

Figure 7-8 XYZ outputs for the expander points lateral points (on the other sides regarding to the control positions). The arrows show the expander modes.

The obtained results indicate three amplifications of the input due to the first models of the expander that was not properly controlled by the two control accelerometers at the following frequencies:

- F1=222.74 Hz (all accelerometers);
- F2=325 Hz (lateral accelerometers MP5-20-21-104);
- F3=528 Hz (all accelerometers X-Y directions).

In the range between 110 and 300 Hz the input on 4 columns of the detector is much higher than the nominal input, as shown in the Figure 7-8.
The same behaviour is detected for the transversal directions at 528Hz.

These frequencies are corresponding to the high peaks found on the detector output, the following figure shows a measurement point output placed on the lower skin (MP2) during the -12dB low level random vibration test.

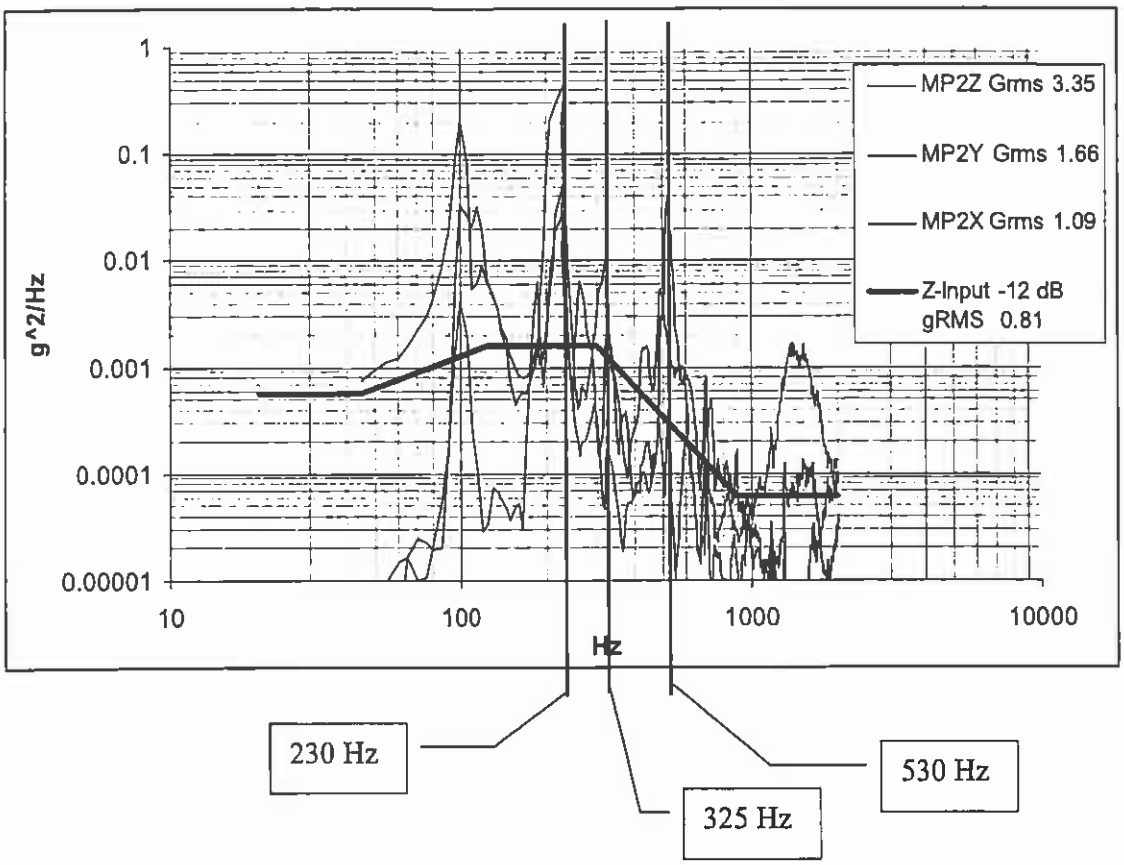

Figure 7-9 MP20 XYZ output for the -12 dB low level random vibration

The expander amplifications are near to three RICH frequency peaks that are relevant to PMT grids vibration; for this reason the over-amplification of the input on 4 of the 8 interface points is considered as one of the causes of the high response detected.

In order to limit this modal coupling and over-excitation due to the expander modes a change in the control setup has been tested.

8. CONTROL SETUP IMPROVEMENT

In order to investigate and limit the over-excitation due to the expander modes a change in the control setup has been adopted. Two additional control accelerometers (CP3 and CP4) have been added near MP104 and MP20, see Figure 7-1.

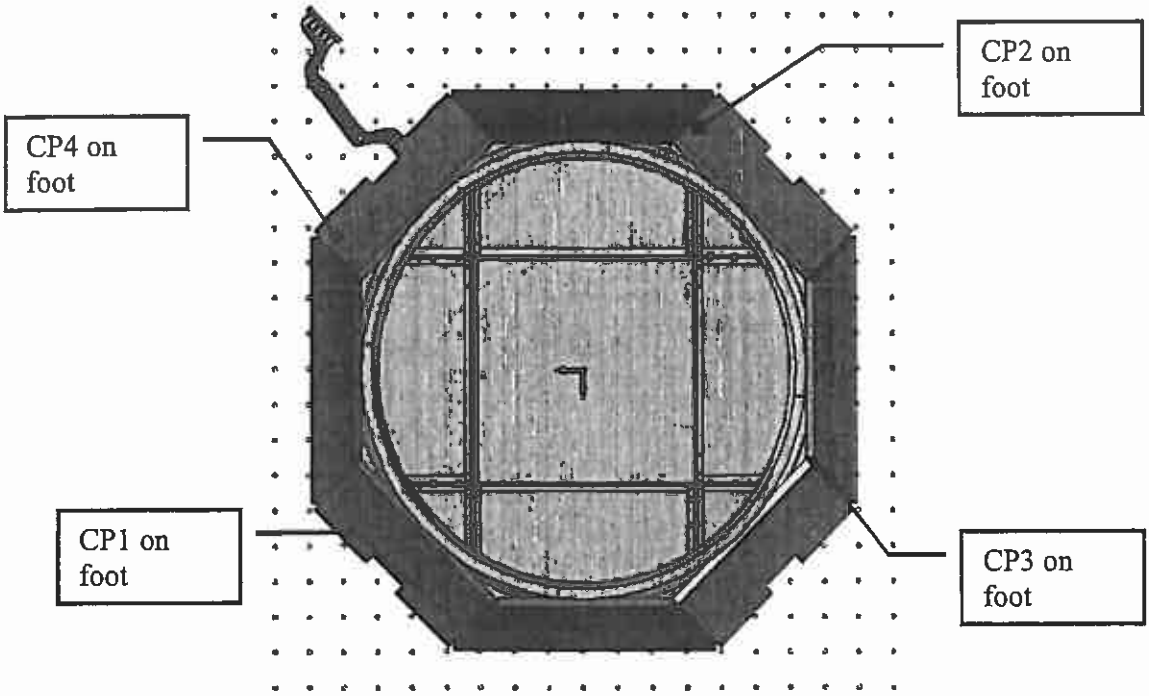

Figure 8-1 New control Points position

Using this improved control setup (control technique: maximum) a RS has been performed. The following figures show the resulting control and the expander outputs.

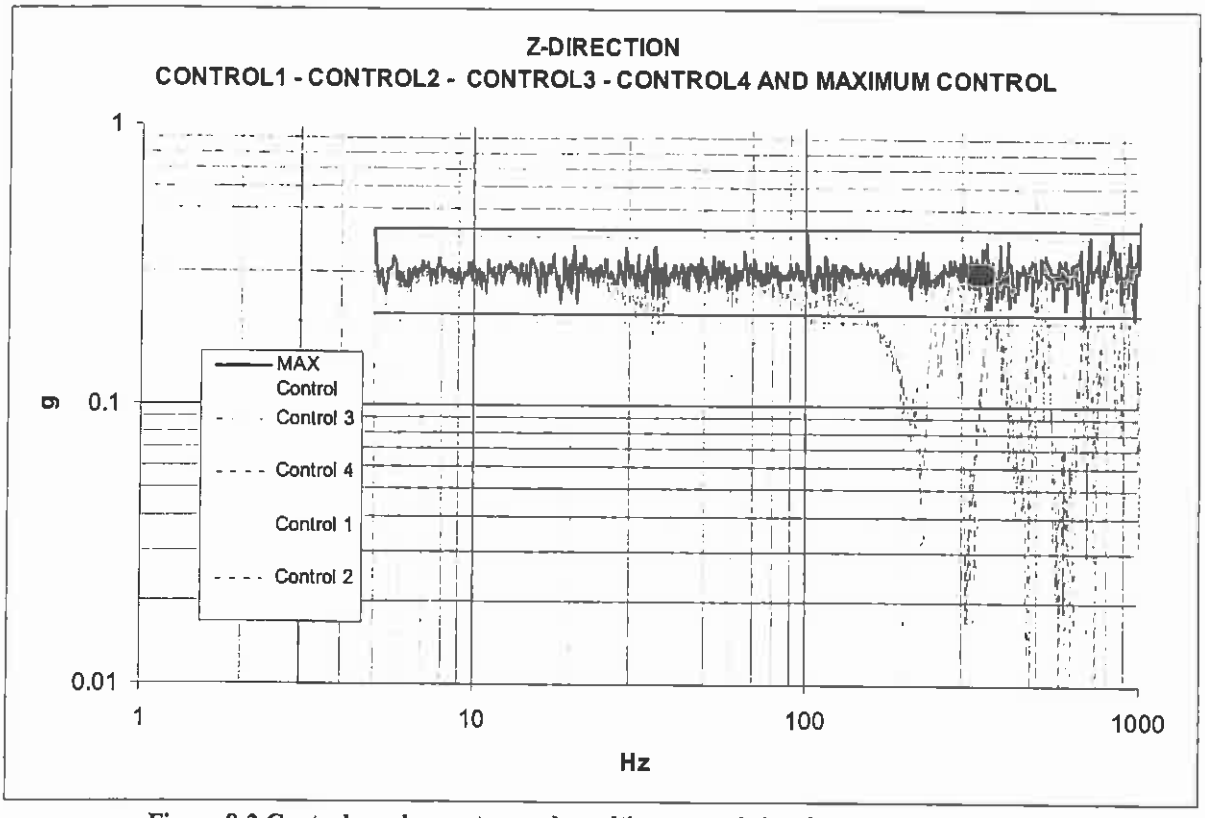

Figure 8-2 Control accelerometers and resulting control signal outputs in Z direction

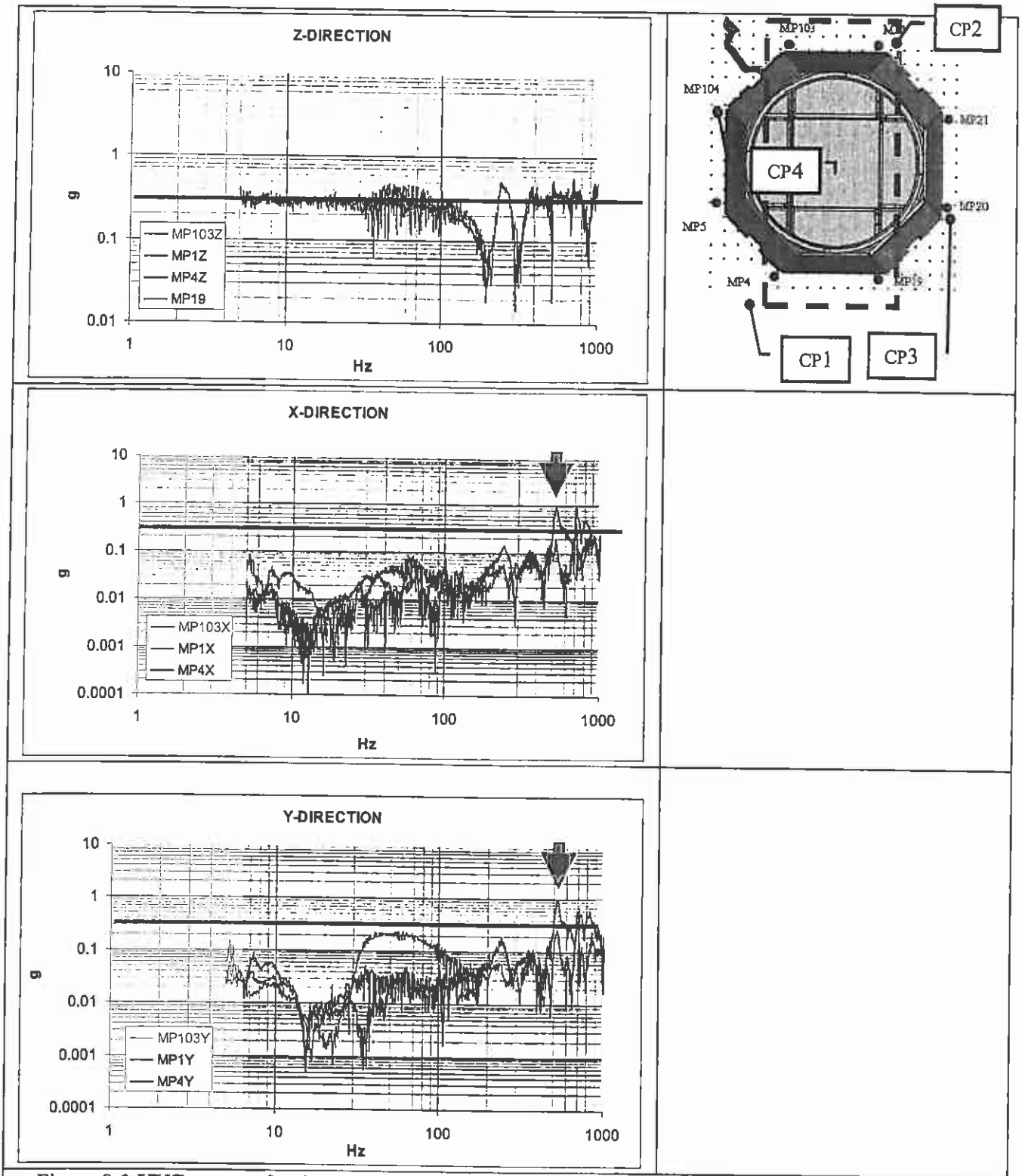

Figure 8-3 XYZ outputs for the expander points near the control points. The arrows show the expander modes.

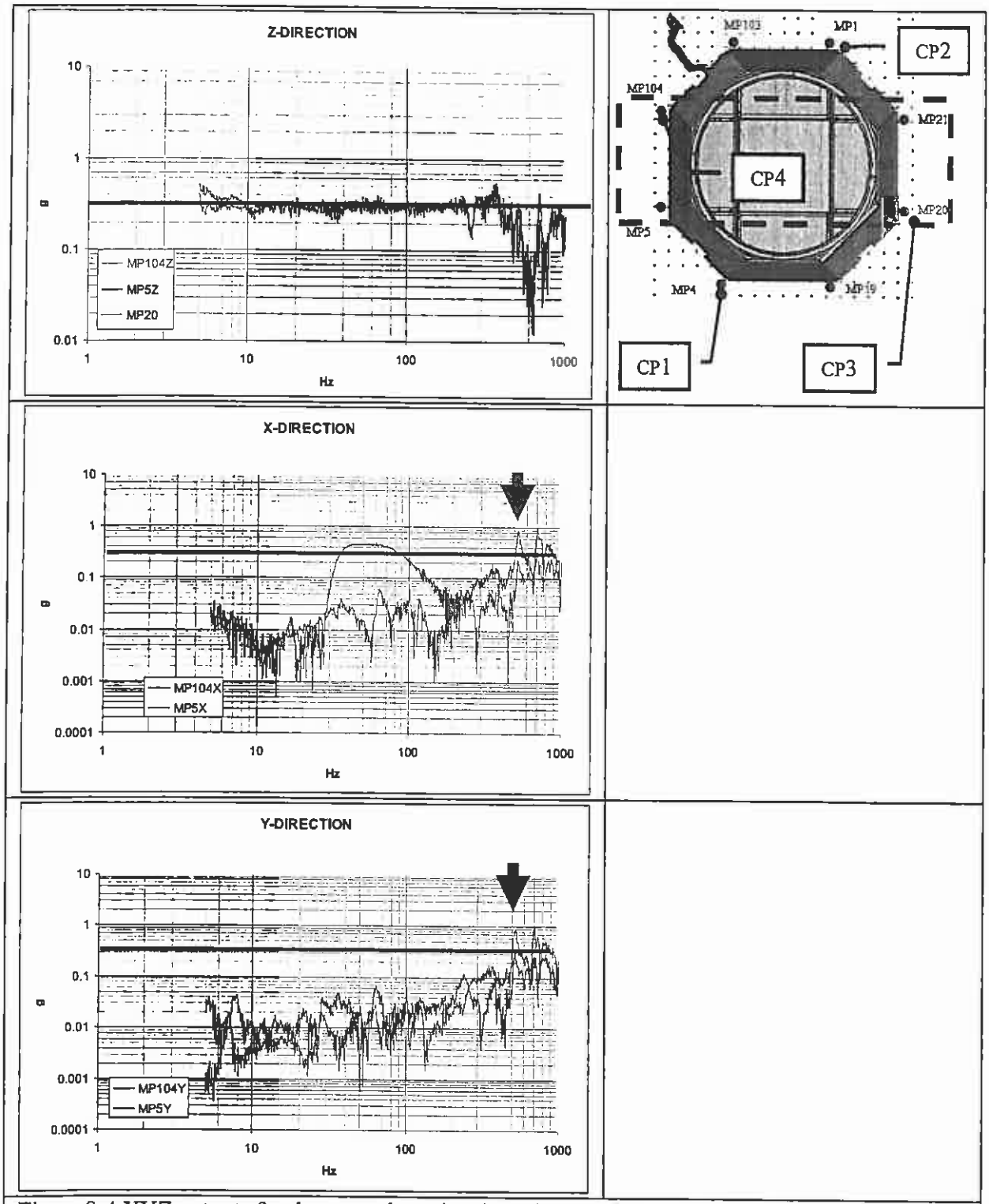

Figure 8-4 XYZ outputs for the expander points lateral points (on the other sides with respect to the control positions). The arrows show the expander modes.

The amplification on expander decreased with respect to the two control, modes are now controlled by the control.

The MP2 outputs obtained with two CP and four CP have been compared in order to quantify the amplification differences.

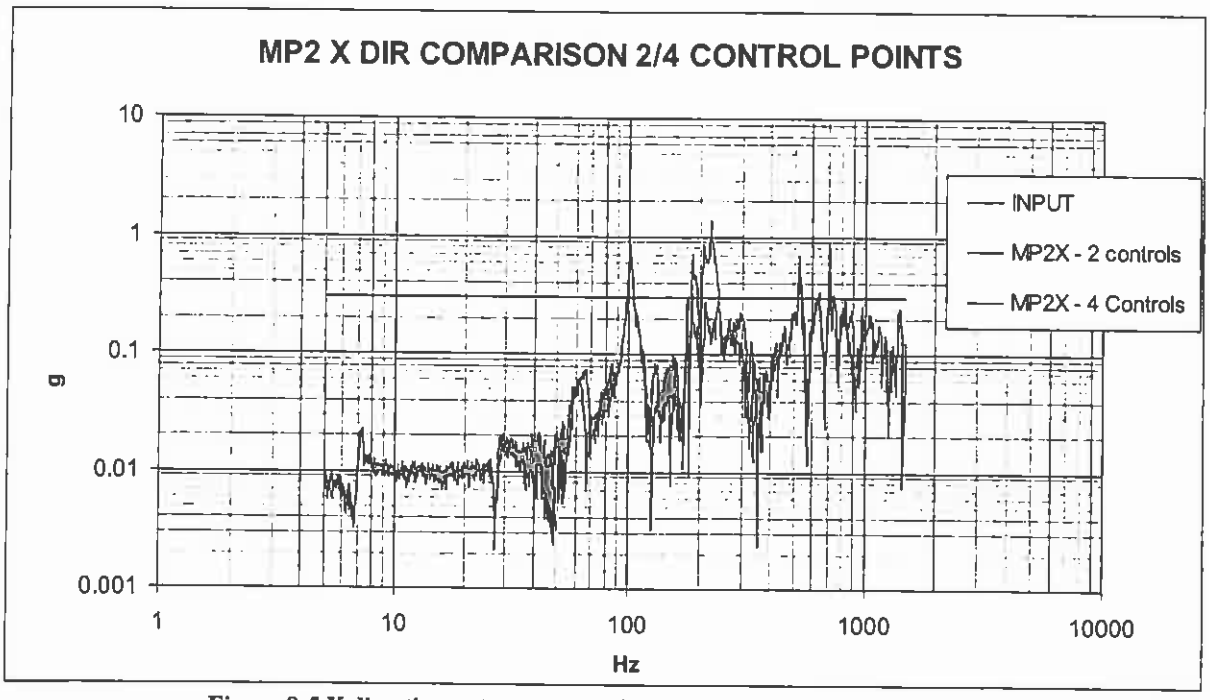

Figure 8-5 X direction outputs comparison between 2 and 4 controls setup

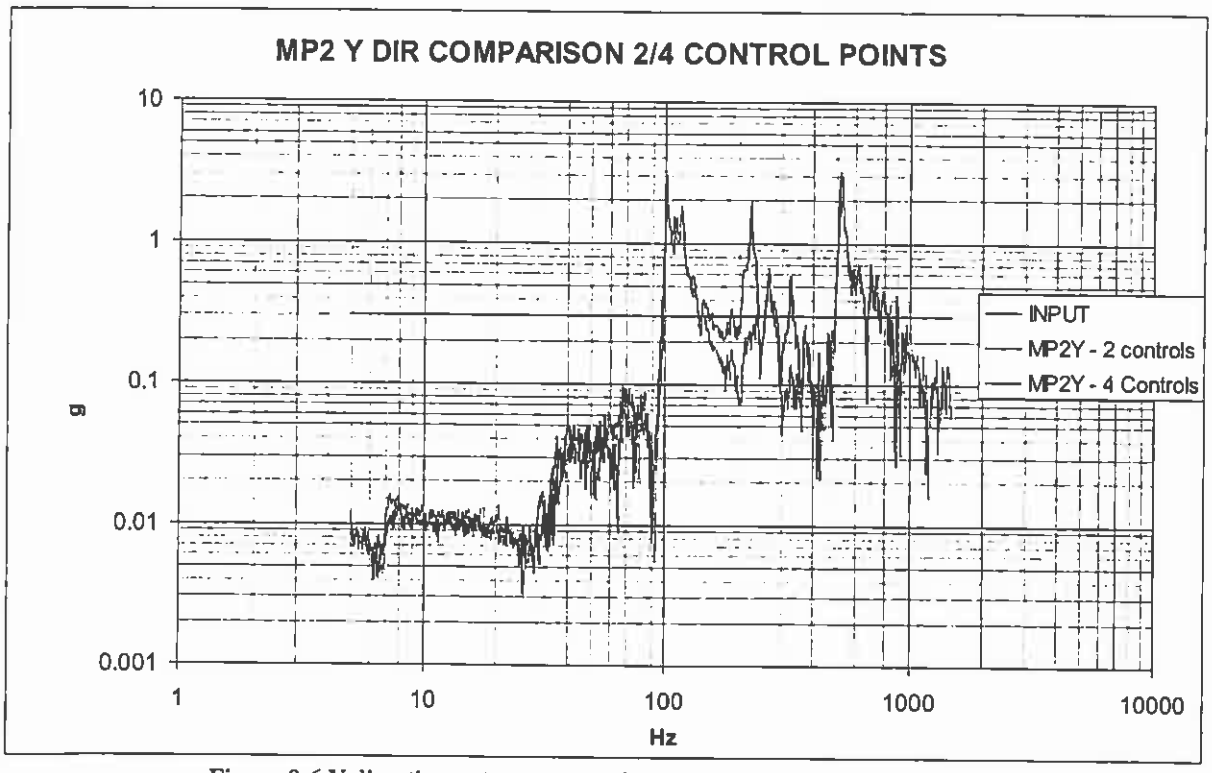

Figure 8-6 Y direction outputs comparison between 2 and 4 controls setup

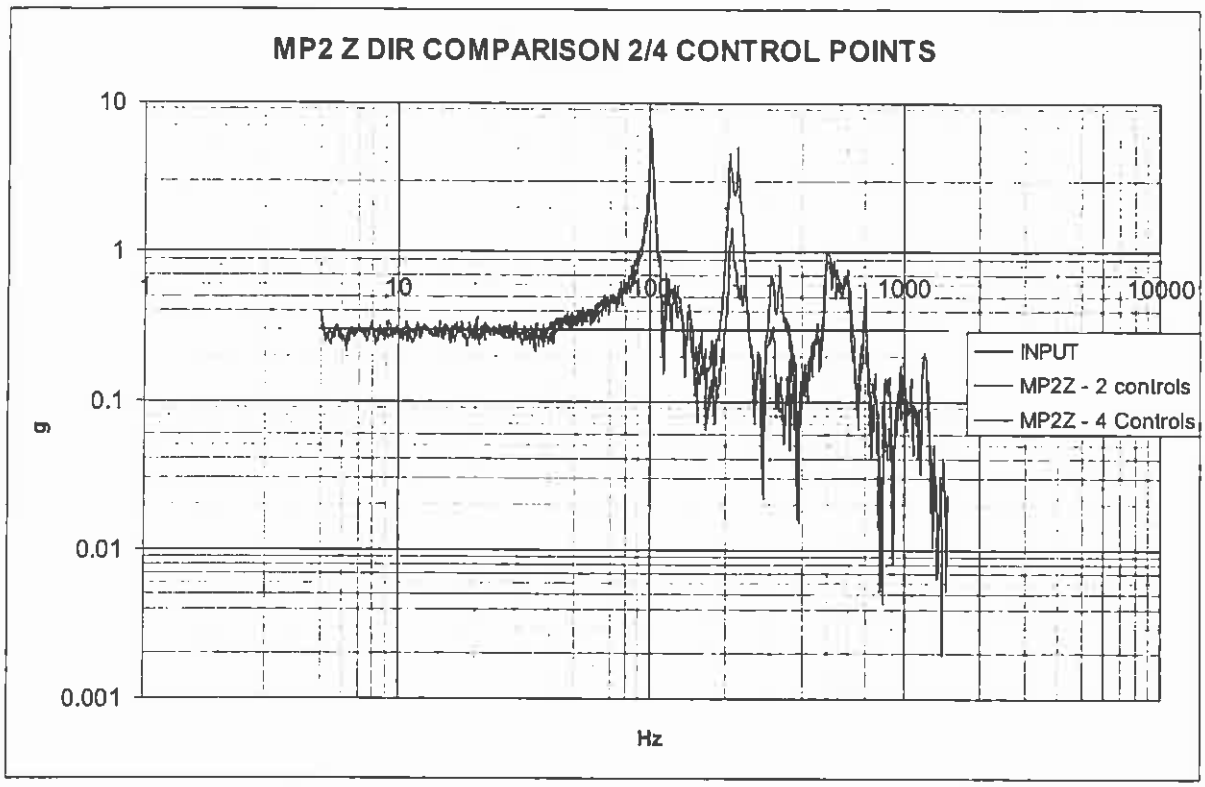

Figure 8-7 Z direction outputs comparison between 2 and 4 controls setup

The amplifications over 200Hz corresponding to the expander modes showed a large decreasing in the RICH response.

With the four control points the second peaks amplifications were in a good agreement with the prediction (the first peak remained with higher response). In the following figures the Acc2 point outputs (Figure 3-1) comparison for FEM prediction and test data are shown; the FEM prediction displayed has been evaluated up to 300 Hz.

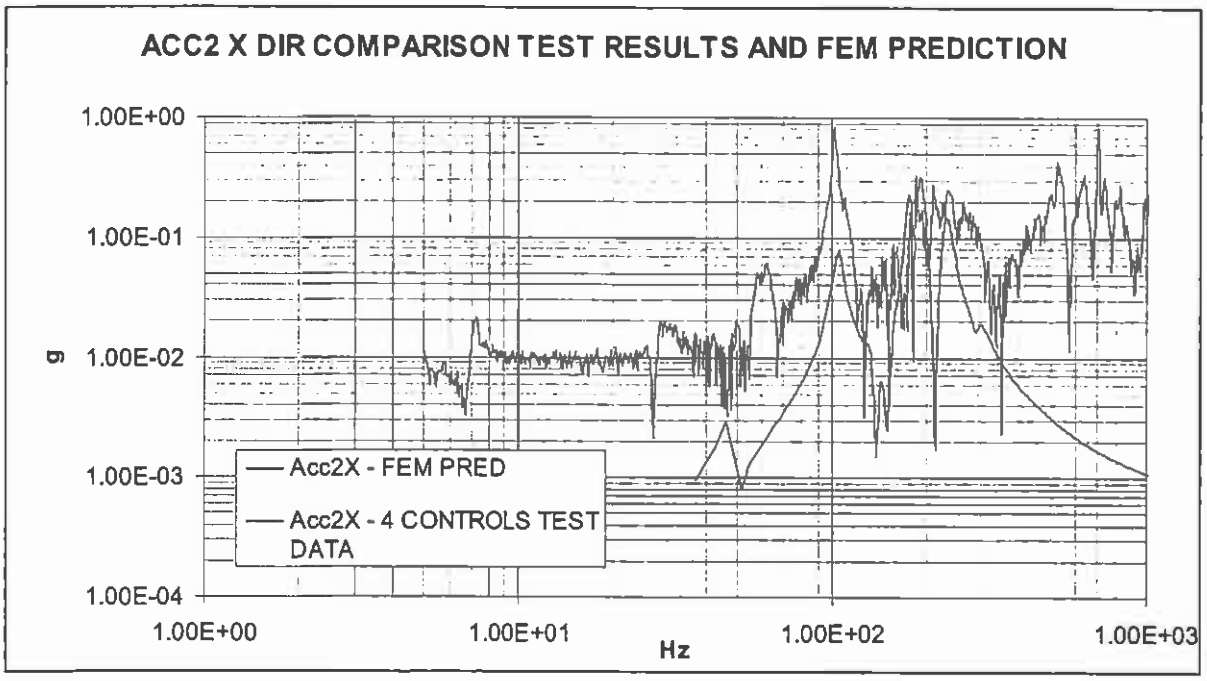

Figure 8-8 Acc2 X direction comparison between RS FEM prediction and test data with 4 control points

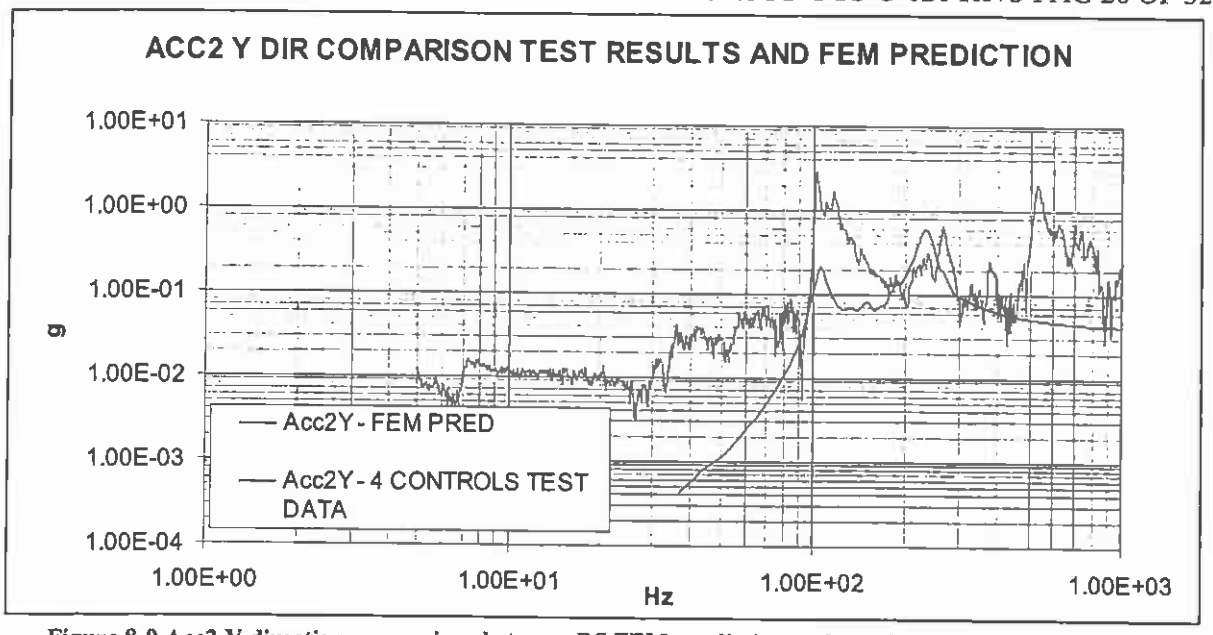

Figure 8-9 Acc2 Y direction comparison between RS FEM prediction and test data with 4 control points

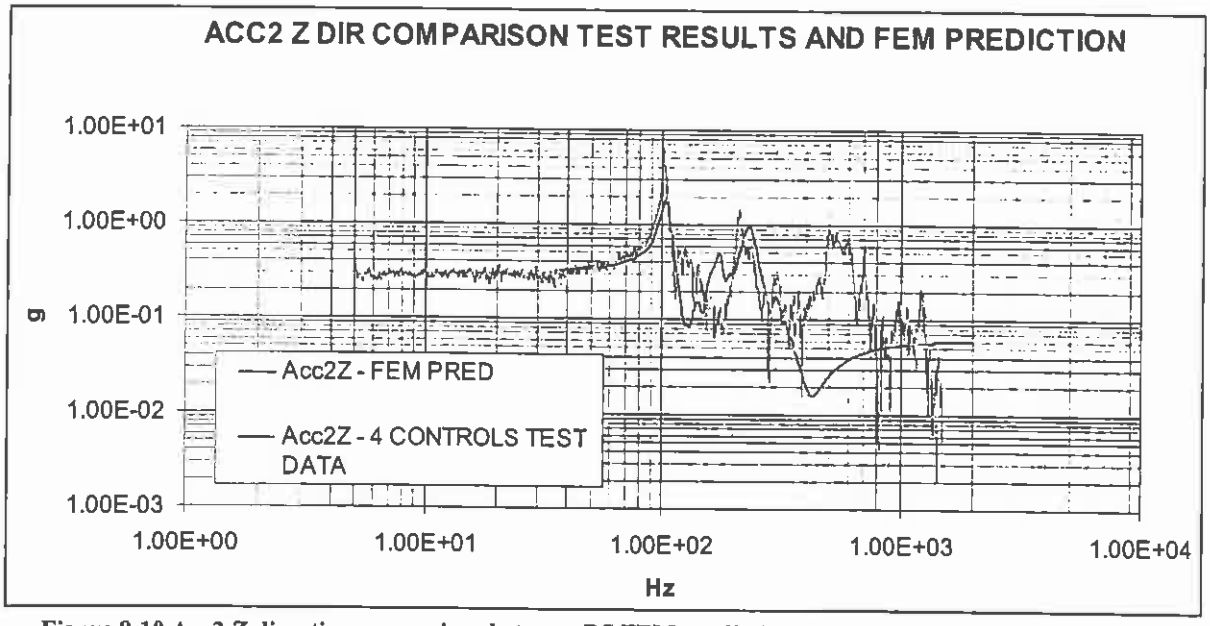

Figure 8-10 Acc2 Z direction comparison between RS FEM prediction and test data with 4 control points

9. NEW CONTROL PERFORMANCES EXTRAPOLATION

Using the transfer functions of each measurement point found with the RS with four control points a prediction of the structural behaviour for a -12dB low level random vibration test has been performed. The following figures show the results for the MP2 extrapolated compared to the MP2 output obtained for the -12 dB low level random vibration test with 2 control points.

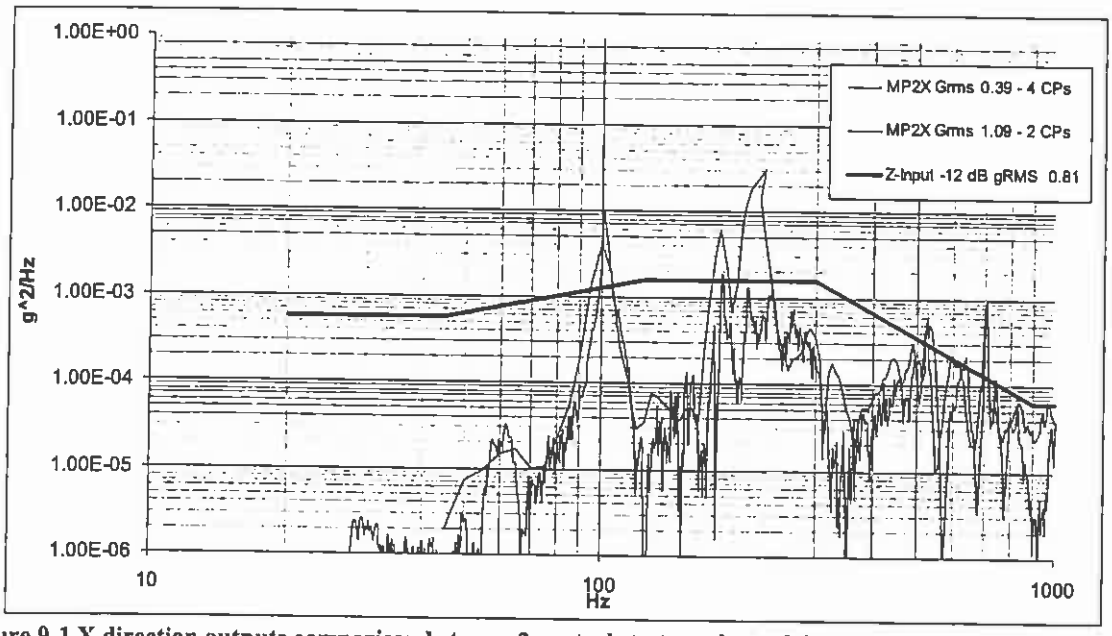

Figure 9-1 X direction outputs comparison between 2 controls test results and 4 controls data extrapolation for the -12 dB low level random vibration

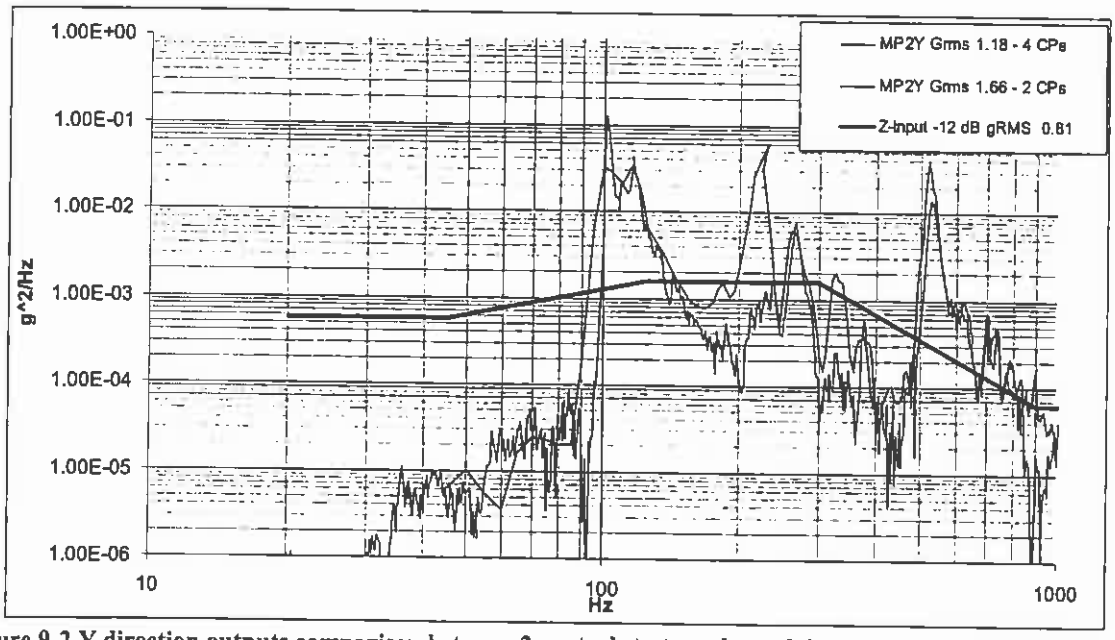

Figure 9-2 Y direction outputs comparison between 2 controls test results and 4 controls data extrapolation for the -12 dB low level random vibration

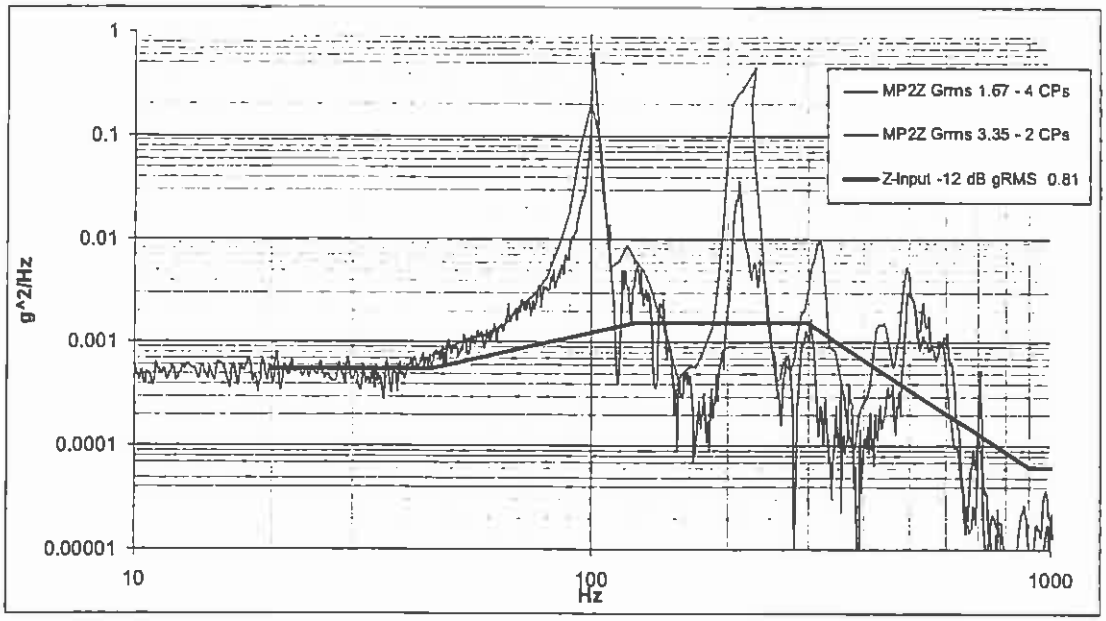

Figure 9-3 Z direction outputs comparison between 2 controls test results and 4 controls data extrapolation for the -12 dB low level random vibration

The following table shows the reduction rate of the g_{rms} calculation for each direction on reference measurement for PMTs.

	X DIRECTION	Y DIRECTION	Z DIRECTION
MP2 TEST DATA [g_{rms}]	1.09	1.66	3.35
MP2 EXTRAP. DATA [g_{rms}]	0.39	1.18	1.67
MP2 g_{rms} Decreasing Rate	64%	29%	49%

Table 9-1 Decreasing rate percentiles for each direction

Using these reduction rates a g_{rms} extrapolation on the lower skin acceleration levels has been performed for the full level random vibration test using four control points for all measurement points of the PMTs. The following table shows the calculated acceleration values (the highlighted row is corresponding to the MP2 position).

2 CONTROL POINTS TEST MEASUREMENT				
Point	g_{rms} X	g_{rms} Y	g_{rms} Z	g_{rms} Tot
Acc1	1.64	8.32	18.24	20.11
Acc2	4.36	6.64	12.96	15.20
Acc3	1.48	9.48	18.28	20.65
Acc4	9.16	1.68	23.6	25.37
Acc5	9.16	2.12	20.4	22.46
Acc6	8.76	0.44	12.12	14.96

4 CONTROL POINTS EXTRAPOLATED DATA				
Point	g_{rms} X	g_{rms} Y	g_{rms} Z	g_{rms} Tot
Acc1	0.59	5.91	9.40	11.12
Acc2	**1.56**	**4.72**	**6.68**	**8.33**
Acc3	0.53	6.74	9.42	11.60
Acc4	3.28	1.19	12.16	12.65
Acc5	3.28	1.51	10.51	11.12
Acc6	3.13	0.31	6.25	7.00

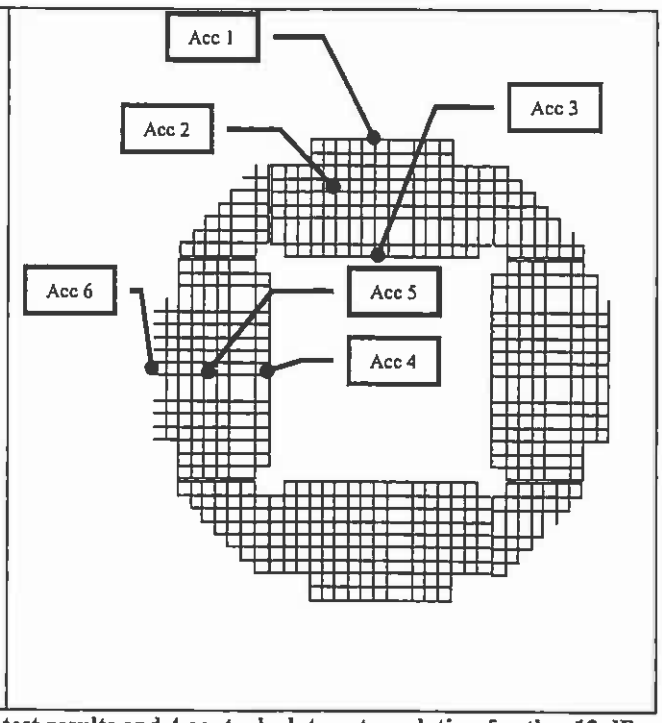

Table 9-2 g_{rms} values comparison between 2 controls test results and 4 controls data extrapolation for the -12 dB low level random vibration

The calculated highest value for Acc 4 (12.6 g_{rms}) is in good agreement to the predicted value of 10 g_{rms} [RD1]. This level is compatible with the estimated MAX g_{rms} reached on the PMT grid lower skin during the single grid vibration test of 11/2006.

In order to decrease the lower skin acceleration a preliminary evaluation of the required notching is calculated.

10. NOTCHING EVALUATION

Using the transfer function for the MP2 and the decreasing rates to evaluate the lower skin accelerometer behaviour ,a possible notching to limit the lower skin response to 11.3 g_{rms} is calculated according to the notching criterion of "RICH SYSTEM VIBRATION PROCEDURE" RICSYS-PR-CGS-007.

Freq. [Hz]	PSD [g^2/Hz]
20	0.009
45	0.009
60	0.012
130	0.012
145	0.025
300	0.025
900	0.001
2000	0.001
Overall g_{rms}	3.08

Notching effect on selected measurement point (MP2)

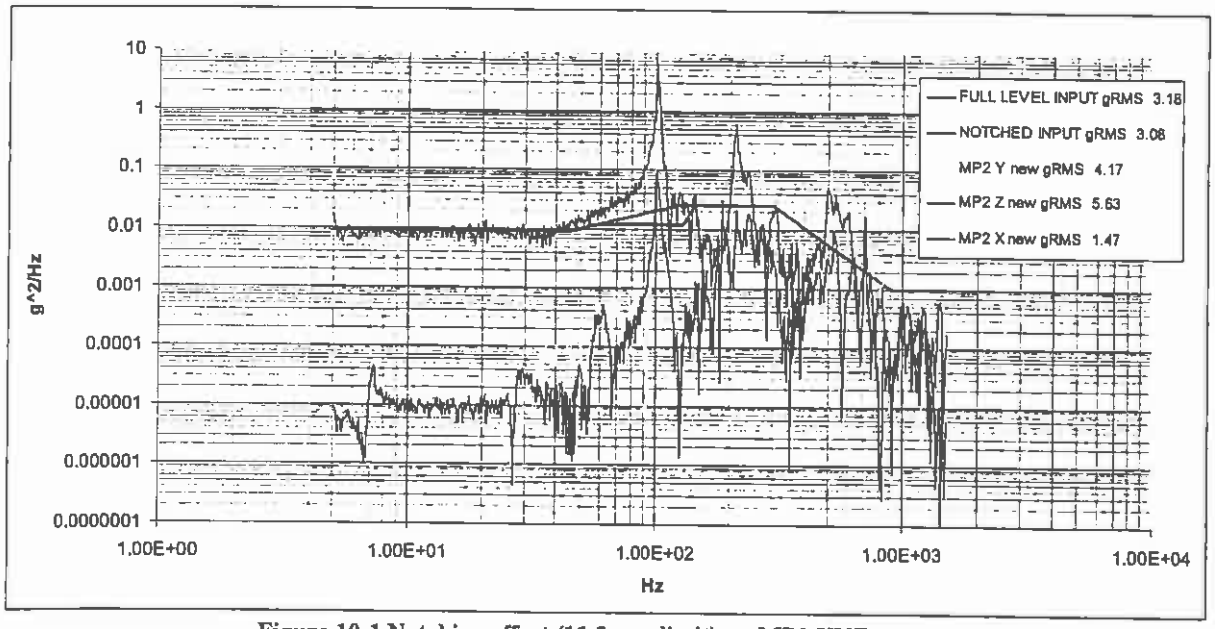

Figure 10-1 Notching effect (11.3 g_{rms} limit) on MP2 XYZ outputs

The following table shows the extrapolated g_{rms} level on all lower skin measurement points.

	g_{rms} - X	g_{rms} - Y	g_{rms} - Z	g_{rms} -Tot
MP 1	0.40	5.23	7.92	9.50
MP 2	1.47	4.17	5.63	7.16
MP 3	0.36	5.95	7.94	9.93
MP 4	2.23	1.06	10.25	10.54
MP 5	2.23	1.33	8.86	9.23
MP 6	2.13	0.28	5.27	5.69

The result is a maximum predicted g_{rms} (root square sum of x,y,z contributions) on the worst lower skin measurement point (MP4) of 10.54 g_{rms}.

11. RICH - USS INSTALLED DYNAMIC BEHAVIOUR CONSIDERATION

Meanwhile an additional investigation about the dynamic environment of RICH installed on the USS structure has been performed; in particular the modal amplification has been analyzed.
The principal considerations are:

- The amplifications seen at PMT level during the random vibration test are due to hard-mounted response of the RICH deriving from a very sharp pump mode in Z direction combined with a vertical excitation coming from the shaker interface that is a conservative test approach if compared to the actual interface to the USS, which allows some compliance.
- All the mechanical junctions between the STS and the RICH (through the USS) dissipate energy during the vibration providing additional reduction between primary structure and RICH interfaces.
- The acoustic vibration does not affect the Z direction vibration of the RICH detector plane acting on the debris shields.
- The RICH Z direction first mode frequency (100 Hz) is quite higher than the first AMS (primary structure) frequency in Z direction (20 Hz, experimentally verified from the AMS STA test);
    - the first structural mode of the USS filters the next modes responses at the equipment level for structure-borne vibration.
      This implies that the MEFL injected at primary structure interfaces will be reduced by dynamic effect and the real input spectrum to the RICH interfaces will be lower than the MEFL in the range above (approximately) 50 Hz.
- **MOST IMPORTANT:** According to AMS Structural Verification Plan, the vibration transmitted through the primary structure to the experiment components will be smaller than Minimum Workmanship Levels (MWL), namely 6.8 g_{rms}.
  From the SVP: "… for mission success it is recommended that vibration testing of the individual electronics components (i.e. PMT) shall be performed to MWL".
  In the RICH specific case the MWL envelopes, both in terms of overall g_{rms} and acceleration PSD levels frequency-wise, the worst case response foreseen in any RICH experiment component (PMTs included) due to structure borne and acoustic excitation.

12. RICH PMTs UPDATED ACCELERATION LIMITS AND TESTING APPROACH

The considerations described in the paragraph 0 (the USS dynamic coupled to the RICH one, and the SVP requirements) allow to input a random spectrum which results in not exceeding the 6.8 g_{rms} on the PMTs.

We consider representative of the flight environment and adequate to verify mission success a notching (shown hereafter) that:

- notching the first and the second mode reduces locally the PMT response peaks limiting the g_{rms} level to 6.8g_{rms}.

-reduces the overall input level from 3.18 to 2.8 g_{rms} (-12%)

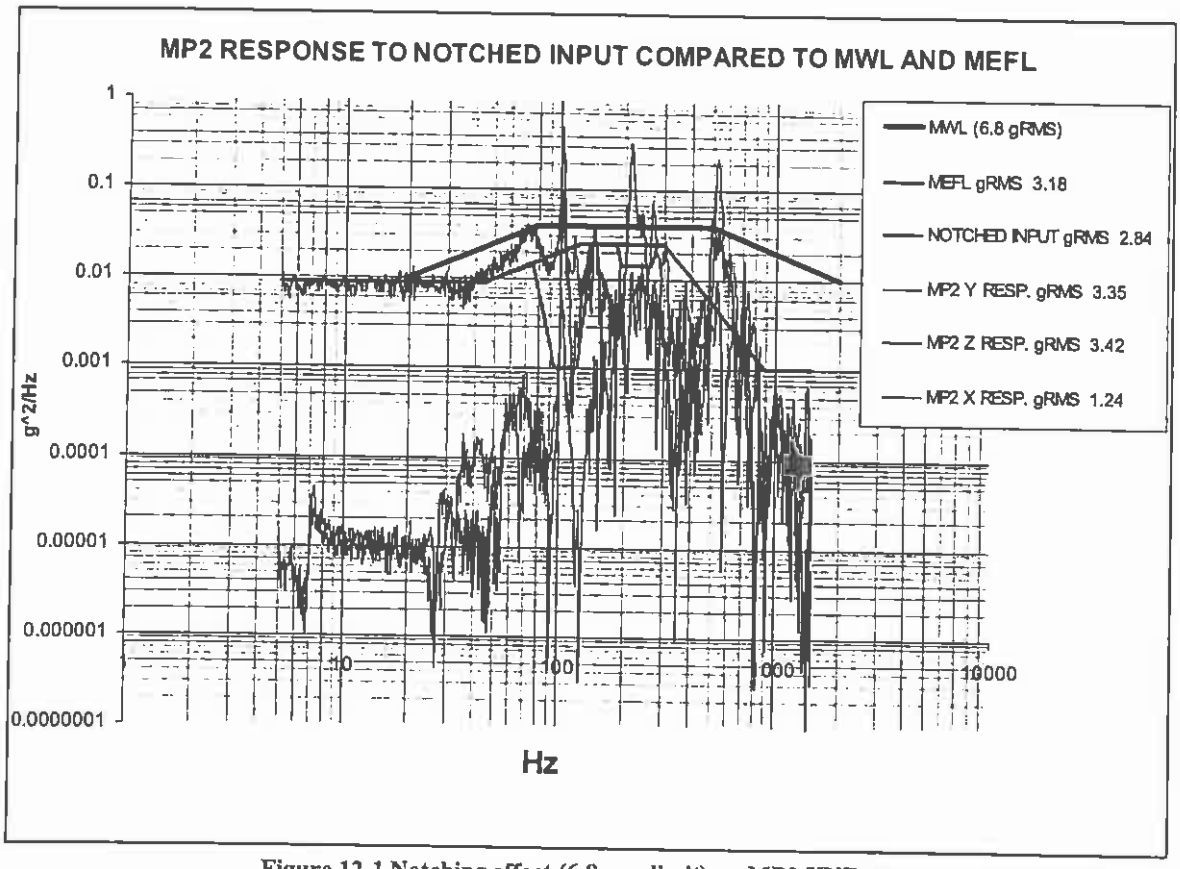

Figure 12-1 Notching effect (6.8 g_{rms} limit) on MP2 XYZ outputs

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From: Tutt, John C [mailto:John.Tutt@escg.jacobs.com]
Sent: Fri 09/11/2007 0.23
To: Giuliano Laurenti
Cc: hungerford1@earthlink.net; carl.lauritzen@escg.jacobs.com; trent.d.martin@nasa.gov
Subject: RICH Vibration Testing

Prof. Laurenti,

As Bill, you, and I discussed on the phone, ESCG has reviewed the proposed notching in the vibration test spectra used by the RICH testing at INTA. Since this is a functional test for mission success and not related to safety, the decision on how to proceed is yours and we have not taken a formal position on this matter. But in our engineering judgment, the notching is a reasonable approach to avoid overtesting the hardware and does not present a significant risk to the PMTs.

Based on the NCR attachment, the 11g predicted response from the original test input appeared to be driven by resonant responses of the hardware at ~100 Hz and ~207 Hz. As I understand it, these are both "drum" modes of the main RICH plate, and thus are very easily excited by vertical inputs at the bottom of the plate. Therefore it is not surprising to see major spikes in the response at these frequencies from the 3.2 grms test input there. During launch, however, the load levels will not be this high. There are two primary sources of random vibration input during launch: mechanically-induced vibration from the Orbiter and acoustically-induced vibration from the payload bay noise environment. Reviewing each of these in turn:

1) Mechanically-induced vibration comes through the physical connections to the Orbiter. The closest one to the RICH is the keel trunnion. The 3.2 grms test environment envelopes the input environment at that trunnion. The vibration level does not transmit perfectly through the structure, however, but instead attenuates every time it passes through an interface with finite damping. By the time this keel vibration reaches the RICH mechanical interfaces, it will have passed through:

a. The keel trunnion/keel block interface, where a noticeable gap (~0.002") was observed during the modal testing in Munich. While this gap is not significant structurally, it will have a damping effect on the motion of the trunnion.

b. The lower centerbody joint, where the ECAL is clamped down with significant force on top of two Teflon plates. These were seen to move during the ECAL sine sweep testing and will also have a significant damping effect.

2) Acoustically-induced vibration, which will come from direct acoustic impingement on the reflector debris shields. Pressure-induced vibration is an inherently lossy phenomenon, so it takes a significant amount of noise to induce a measurable vibration level. In addition, this noise would enter the RICH baseplate through the debris shield attachment points. These are on the side, not the bottom, and would thus have a very difficult time inducing a response in the two modes of concern (100 Hz and 207 Hz), because these are primarily z-direction drum modes.

As I mentioned before, this is a mission success issue, so it is your decision on whether or not to accept this risk. But based on my experience with flight hardware, I do not see a significant problem.

Regards,
Chris

Chris Tutt

Project Manager

Engineering and Science Contract Group

Jacobs Sverdrup

2224 Bay Area Blvd M/C B2SC

Houston, TX 77058

(281) 461-5703

Annex C to NCR-RICHSYS-CGS-C-020 Rev. 3

1/30

RICH VIBRATION TEST RESULTS SUMMARY

INTRODUCTION

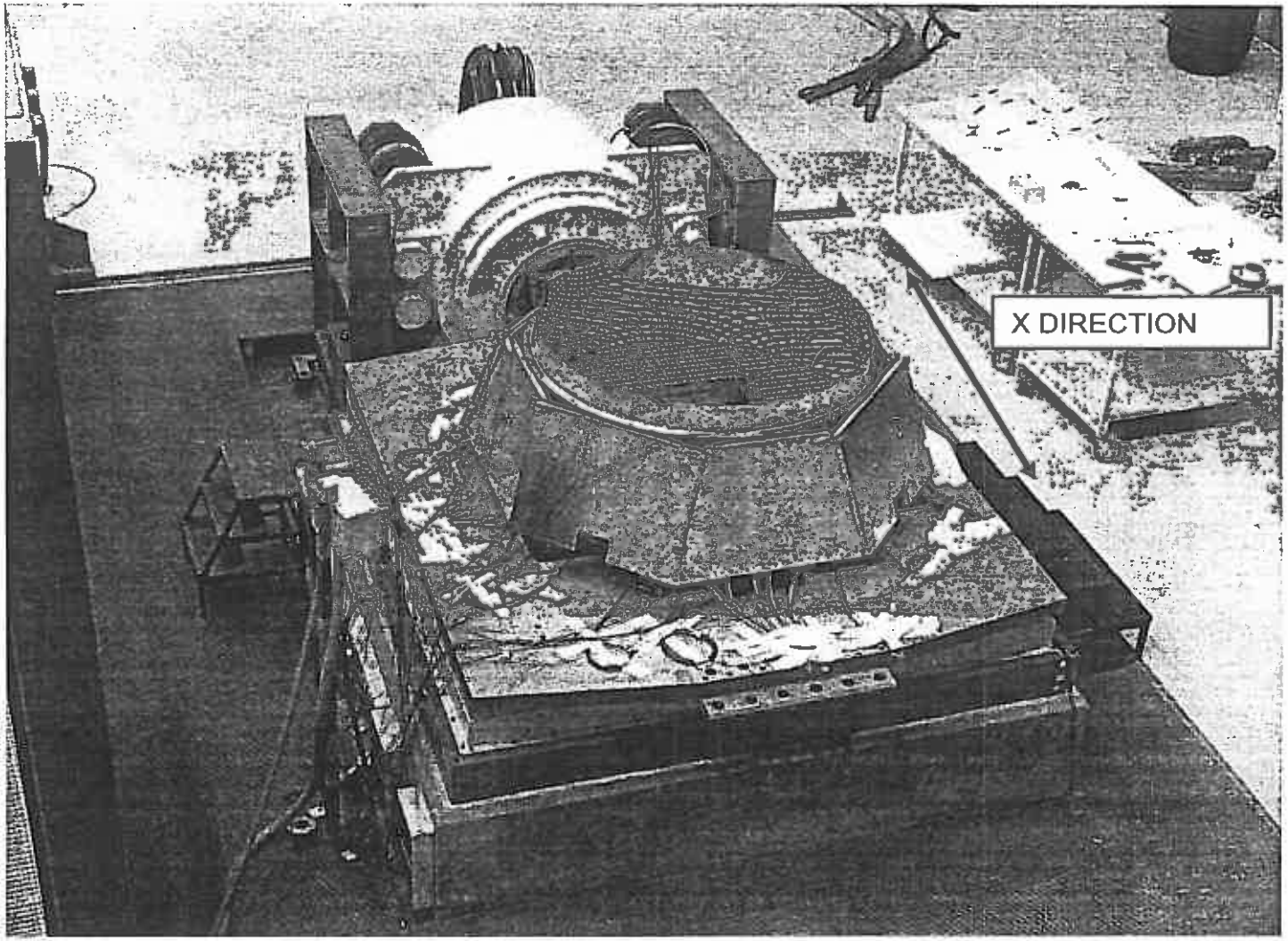
This presentation shows the results summary of the RICH SYSTEM Flight model (FM) vibration. The test has been executed in the INTA facility (Madrid), in particular:

X DIRECTION: 11-15/10/2007
Y DIRECTION: 16-17/10/2007
Z DIRECTION: 18-19/10/2007 and 10-13/12/2007

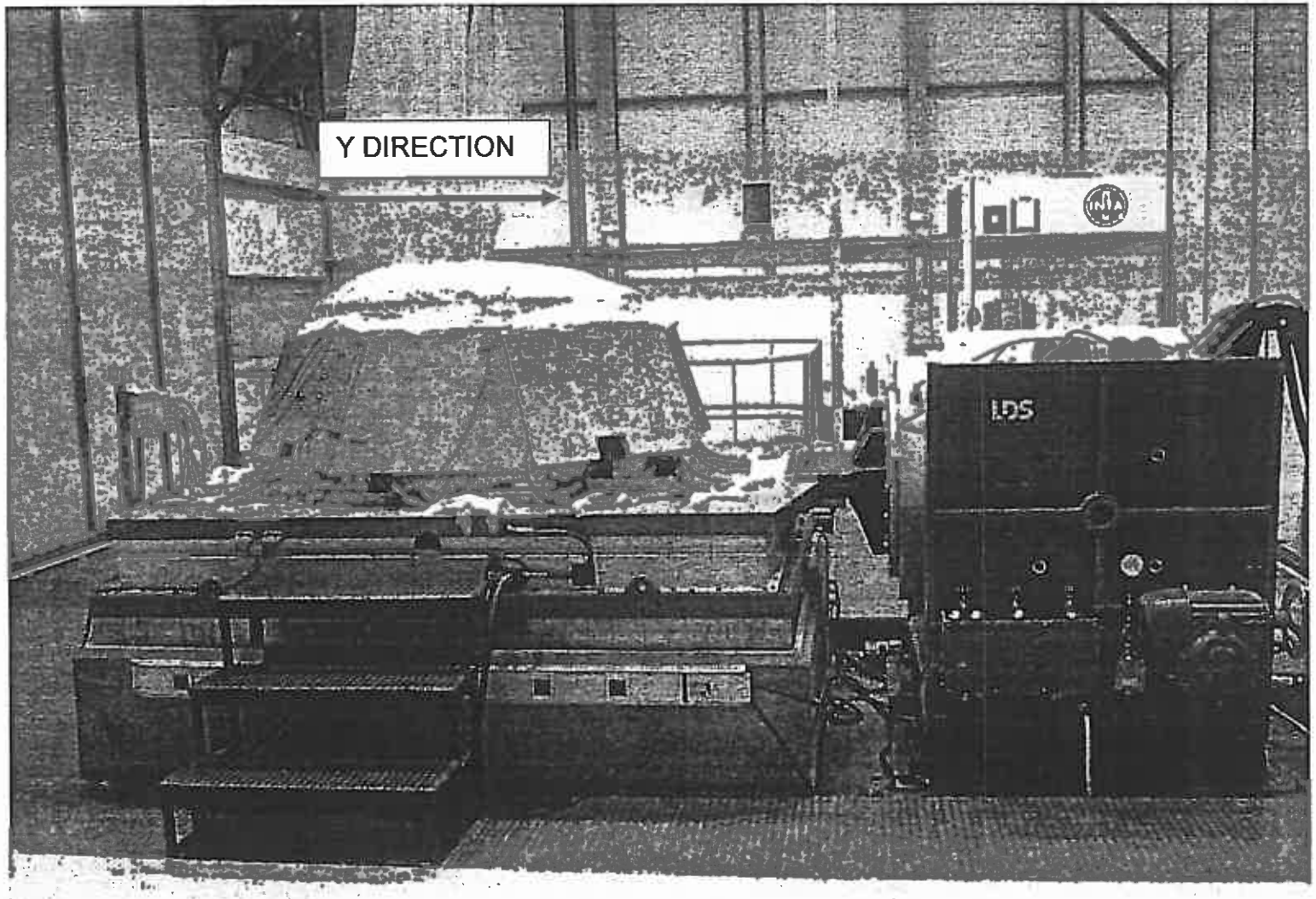
TEST PARTECIPANTS

NAME	COMPANY\ INSTITUTE	ROLE	RESPONSABILITY
A. Bursi	CGS	Test conductor	-Test conduction -Compilation of Step by step procedure -PA\QA management
G. Laurenti	INFN	Customer	-Test supervisor
C. D. Grinzo	CIEMAT	Test Engineer	-UUT transportation and integration -Support to Facility manager for integration of UUT on fixture -Support to test conductor
A. Hurtado	INTA	Facility test manager	Facility management and interface to Test Conductor

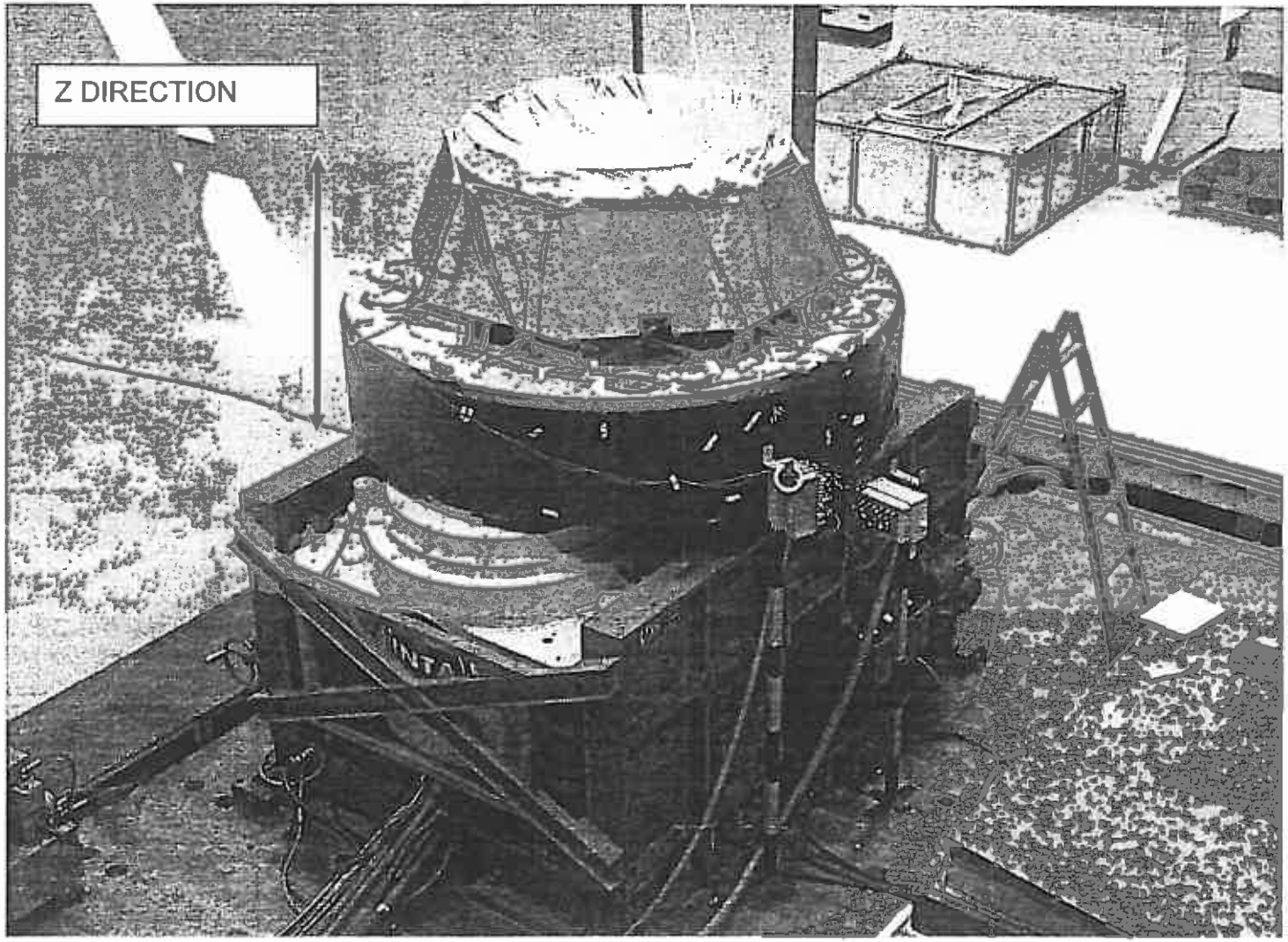
TEST SETUP: X DIRECTION



TEST SETUP: Y DIRECTION



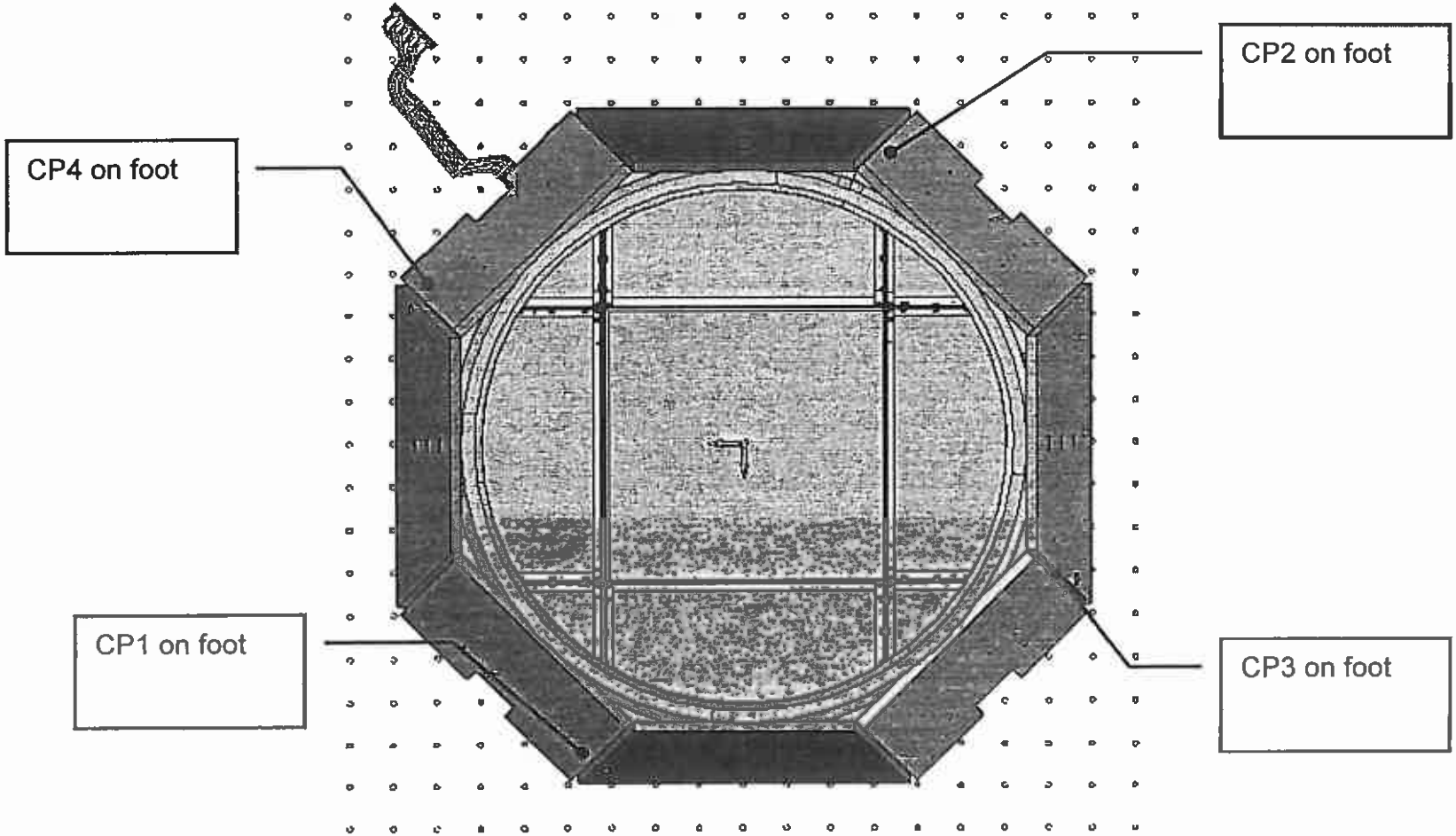
TEST SETUP: Z DIRECTION



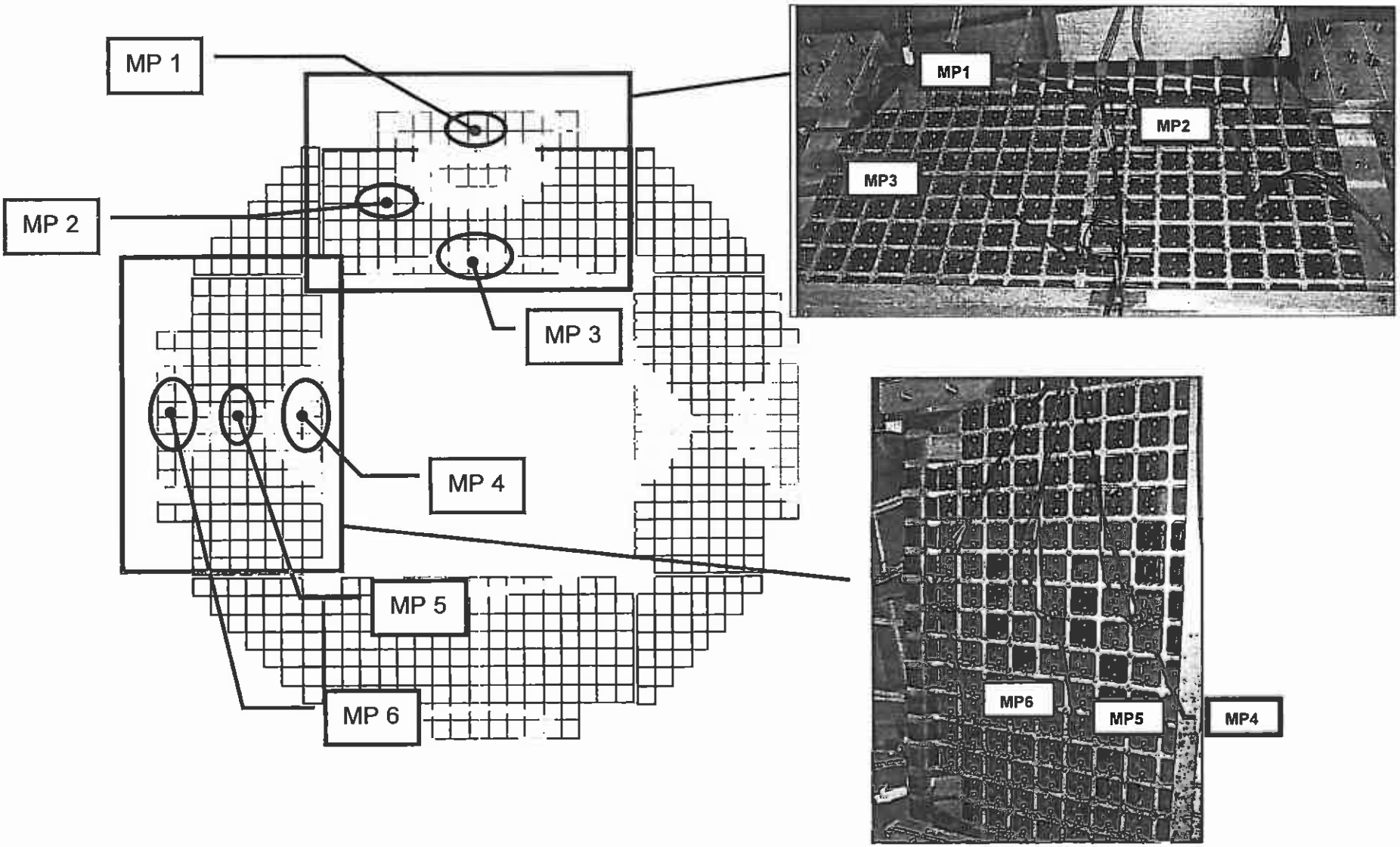
RICH ACCELEROMETER DISPOSITION

SENSOR	LOCATION DESCRIPTION	MEASURED AXIS	REMARKS
CP 1-2	FIXTURE	Excited axis + CROSS AXES	Pilot on excited axis
CP 3-4	FIXTURE	Excited axis	Pilot on Z axis. Used to perform only the Z direction test. Not used for X and Y directions.
MP 1-6	RICH – grids	X, Y and Z	
MP 7-11	RICH– main structure	X, Y and Z	
MP 12-15	RICH– reflector	X, Y and Z	
MP 16-21	RICH– debris shields	X, Y and Z	

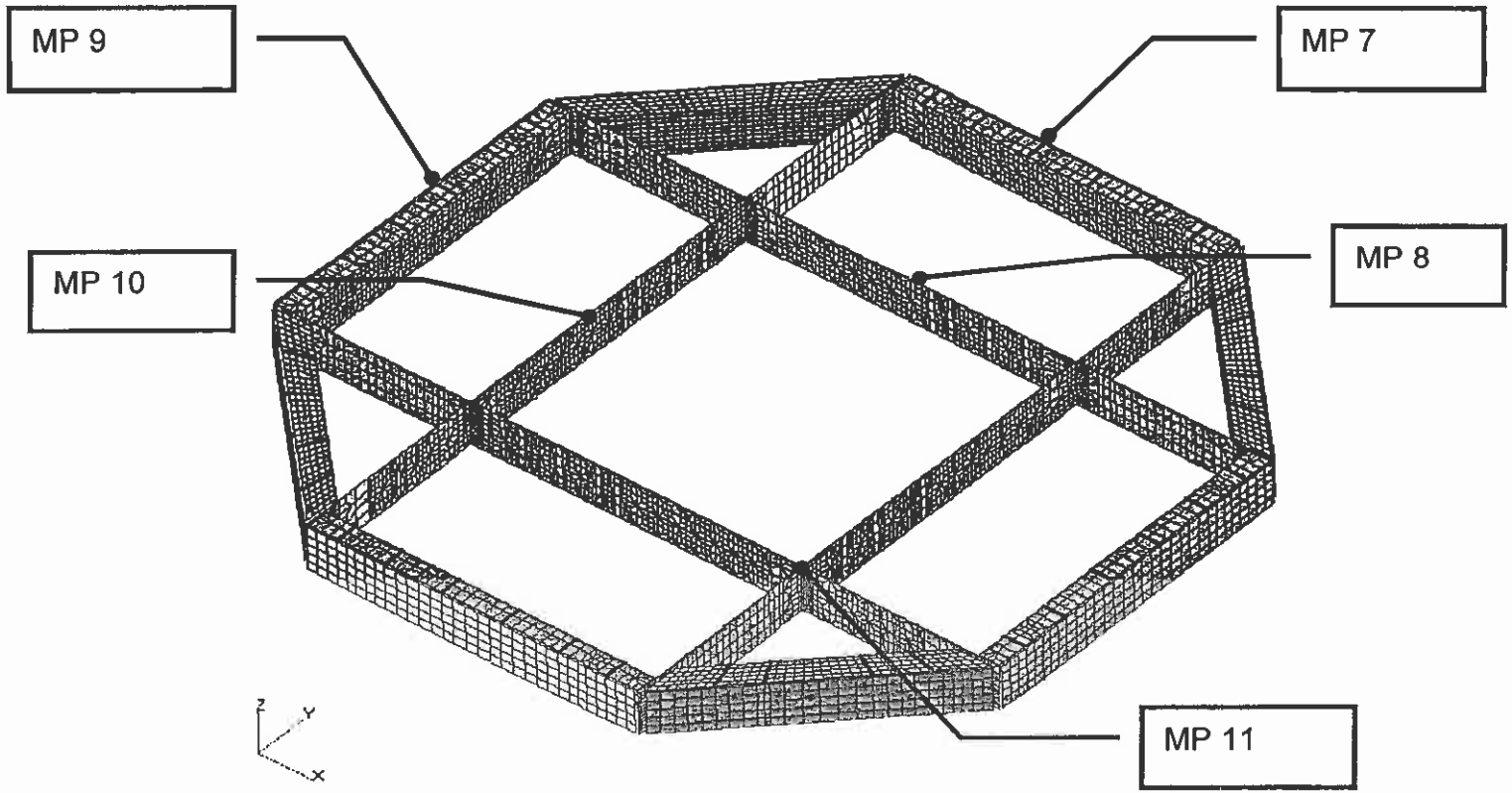
CONTROL POINTS



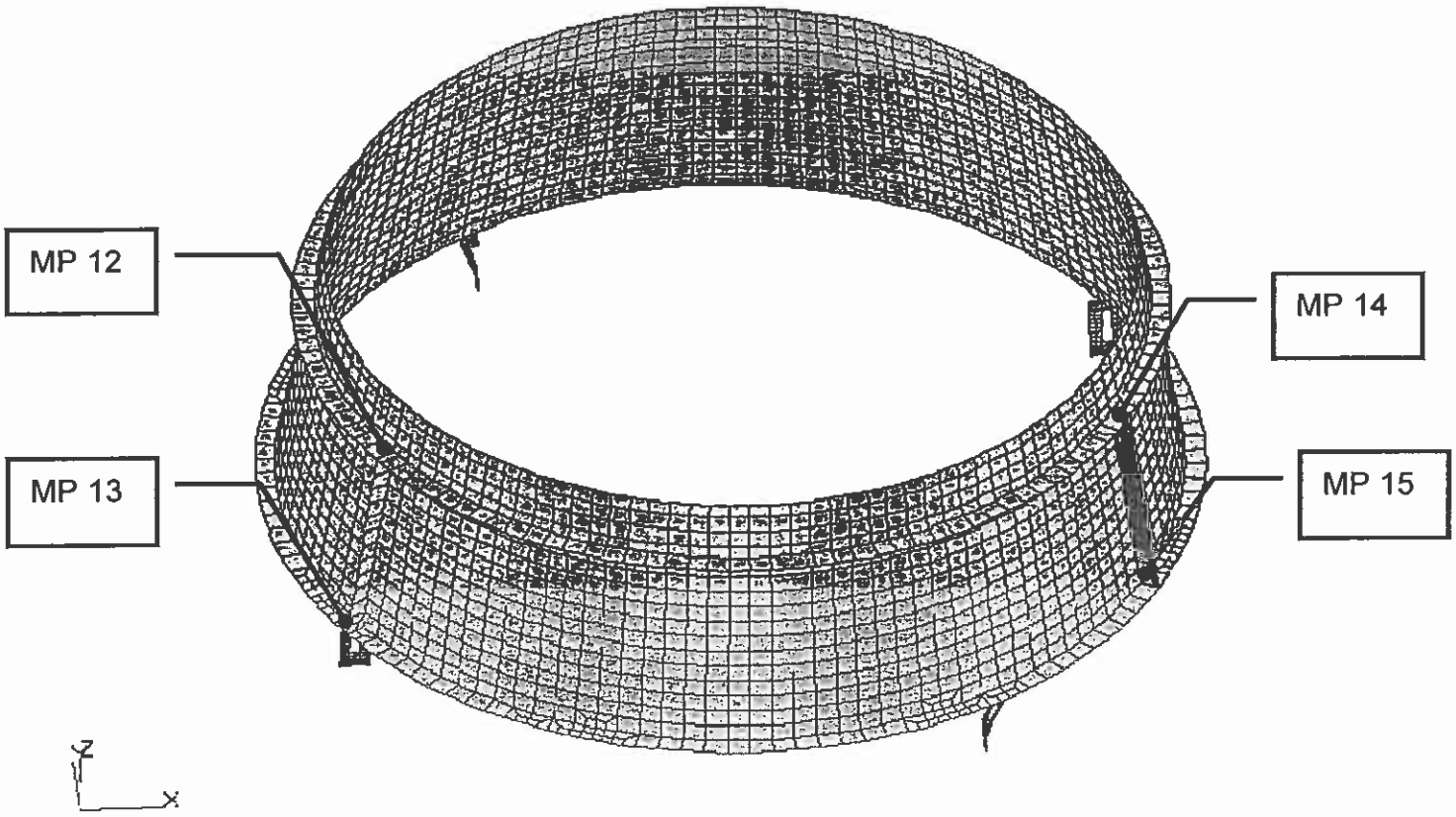
GRID MEASUREMENT POINTS



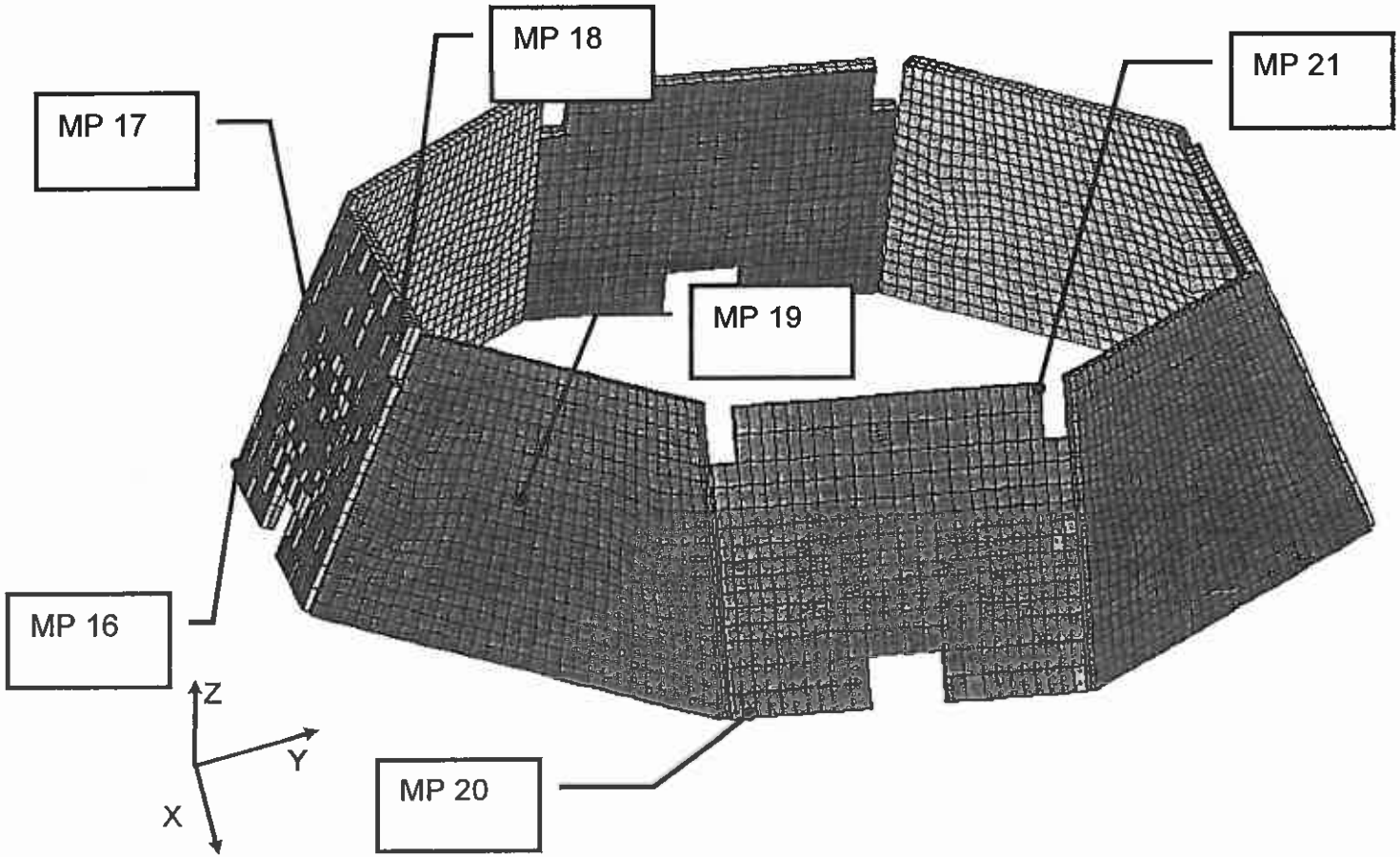
STRUCTURE MEASUREMENT POINTS



REFLECTOR MEASUREMENT POINTS



DEBRIS SHIELD MEASUREMENT POINTS



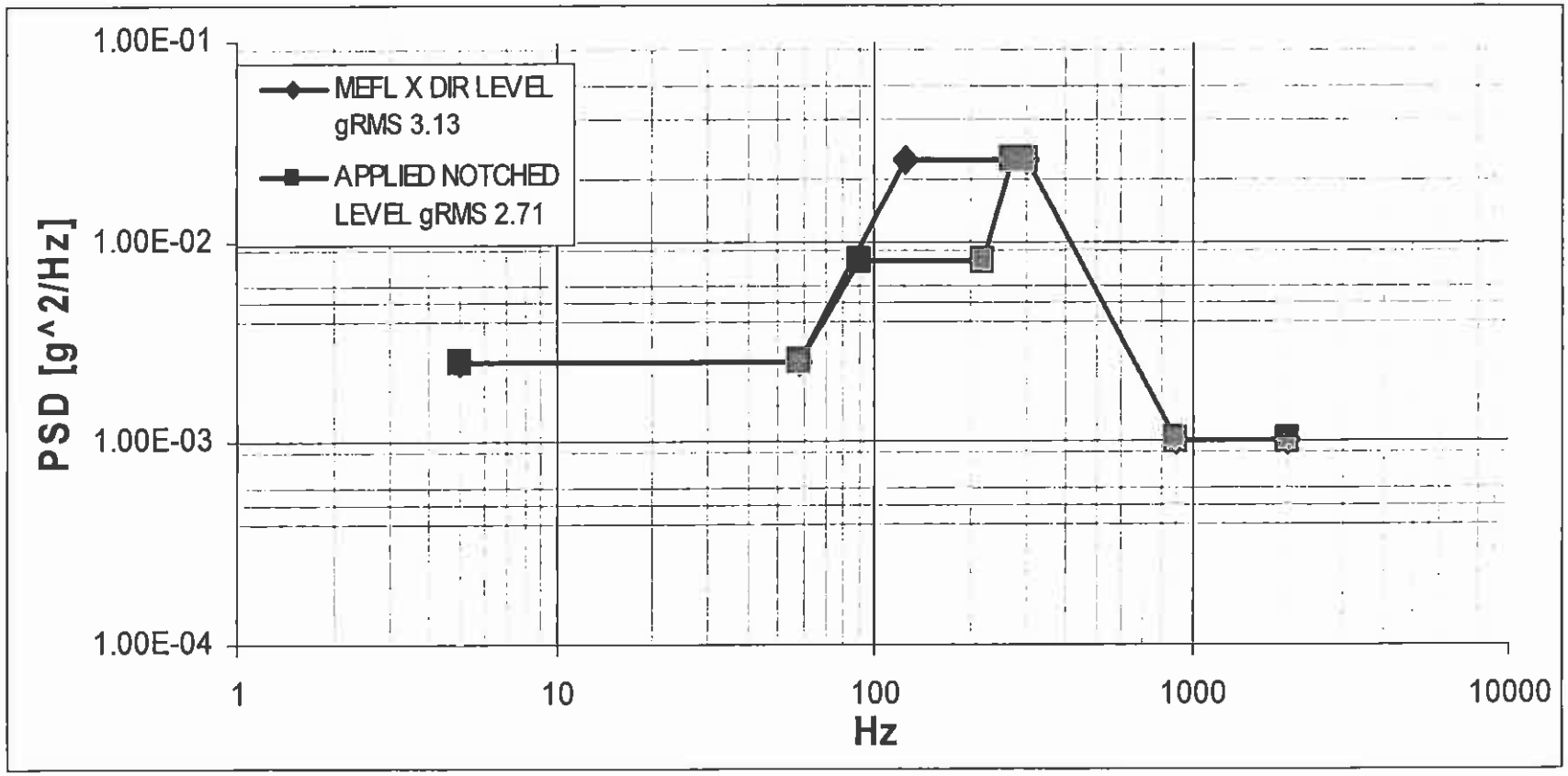
RICH VIBRATION TEST SEQUENCE

For each vibration axis the following sequence has been applied:

- Resonance search before random vibration
- Low level random vibration
- Full level random vibration
- Resonance search after random vibration

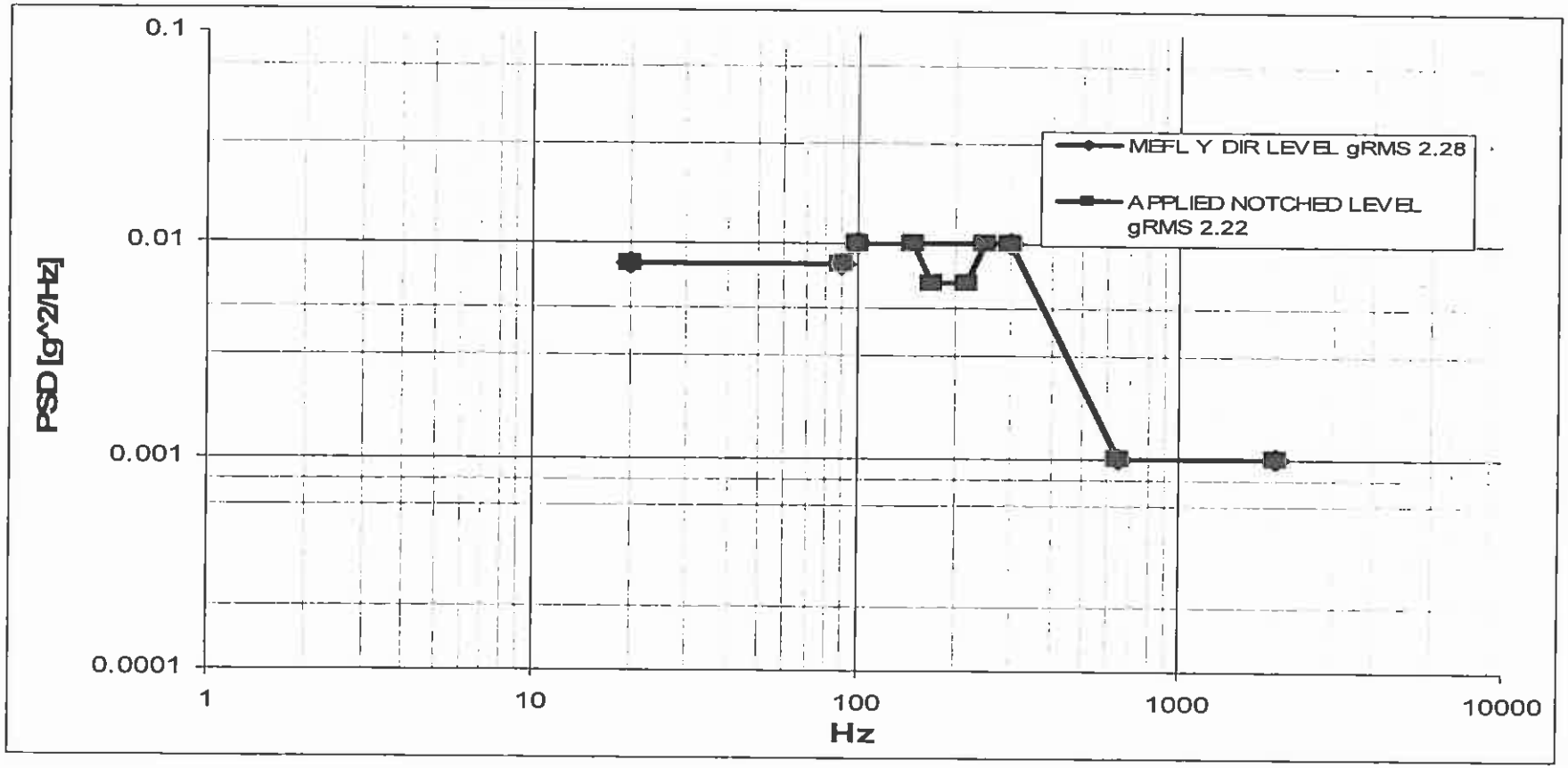
RANDOM TEST LEVEL: X DIRECTION

In agreement with INFN the applied random vibration full level was the following:



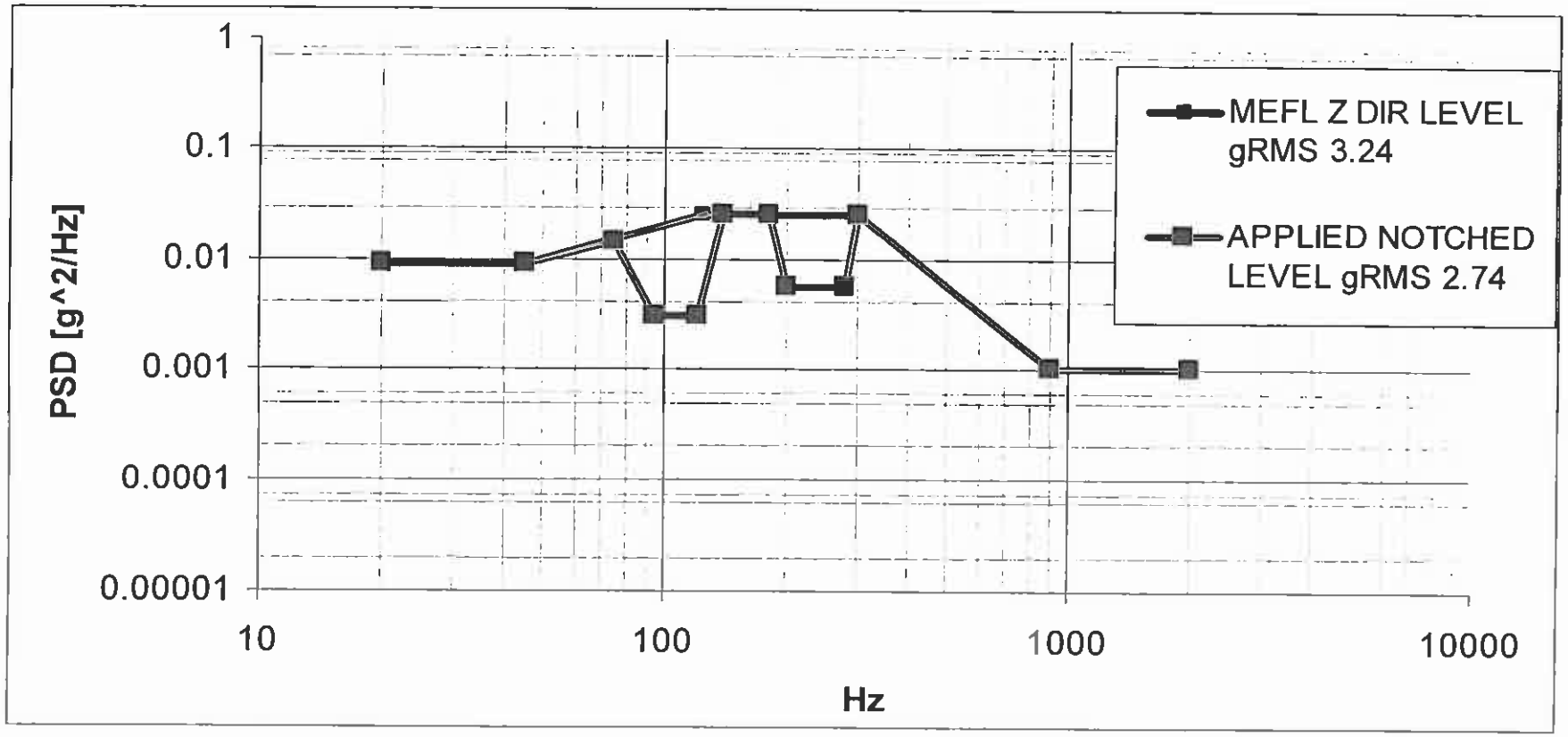
RANDOM TEST LEVEL: Y DIRECTION

In agreement with INFN the applied random vibration full level was the following:



RANDOM TEST LEVEL: Z DIRECTION

In agreement with INFN the applied random vibration full level was the following:



X DIRECTION TEST RESULTS: MODAL BEHAVIOUR

MAIN MODE : 110 Hz

RICH DETAILED BEHAVIOUR:

GRIDS:
TWO PEAKS @ f_1=120 Hz and f_2=200 Hz
AMPLIFICATIONS RANGE FROM 6 TO 10.

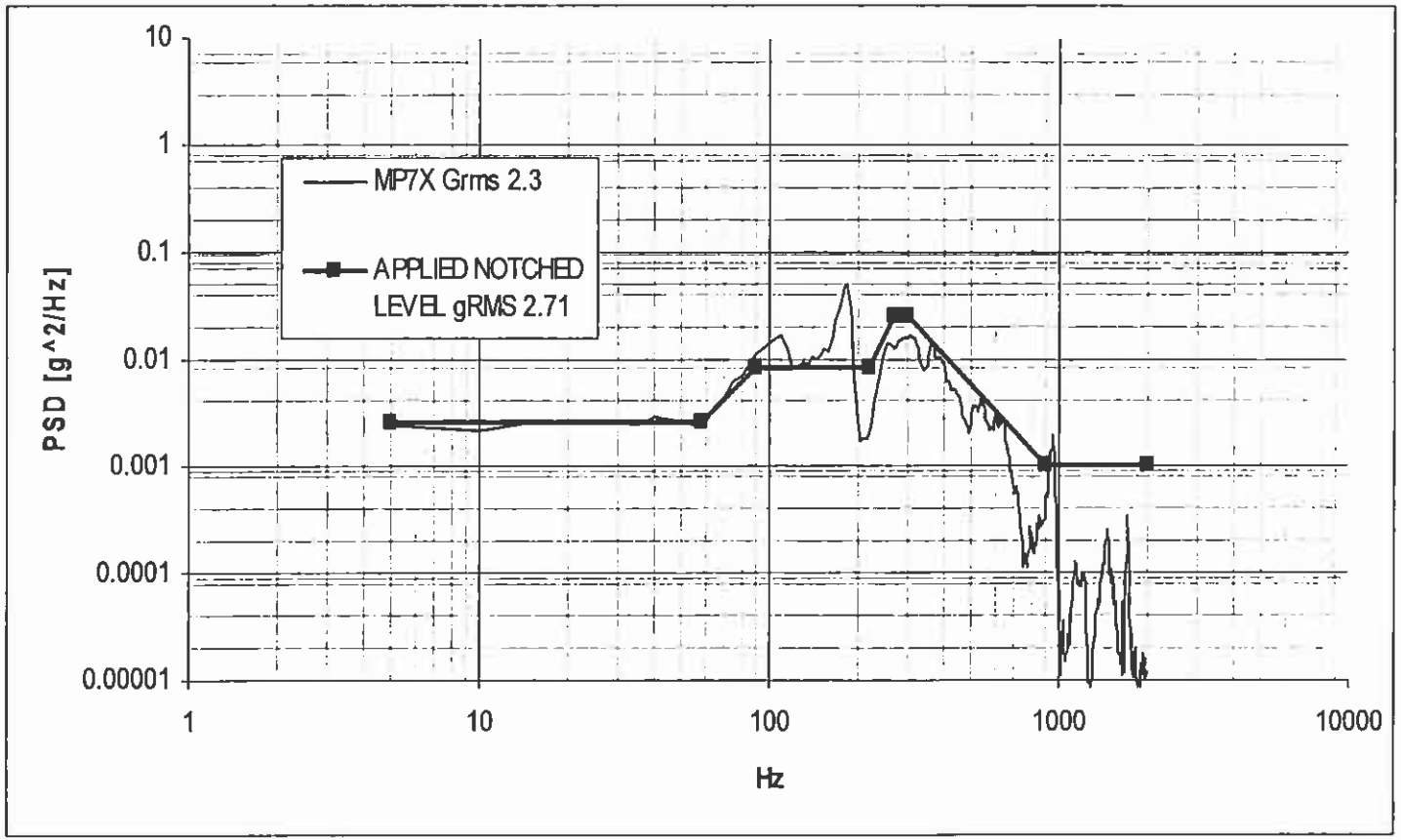
STRUCTURE:
TWO PEAKS @ f_1=110 Hz and f_2=195 Hz
AMPLIFICATIONS RANGE FROM 4 TO 13.

REFLECTOR:
FIRST MODE IS @ f_1=34 Hz
AMPLIFICATIONS RANGE FROM 4 AND 13.

DEBRIS SHIELD:
TWO PEAKS @ f_1=85 Hz and f_2=110 Hz

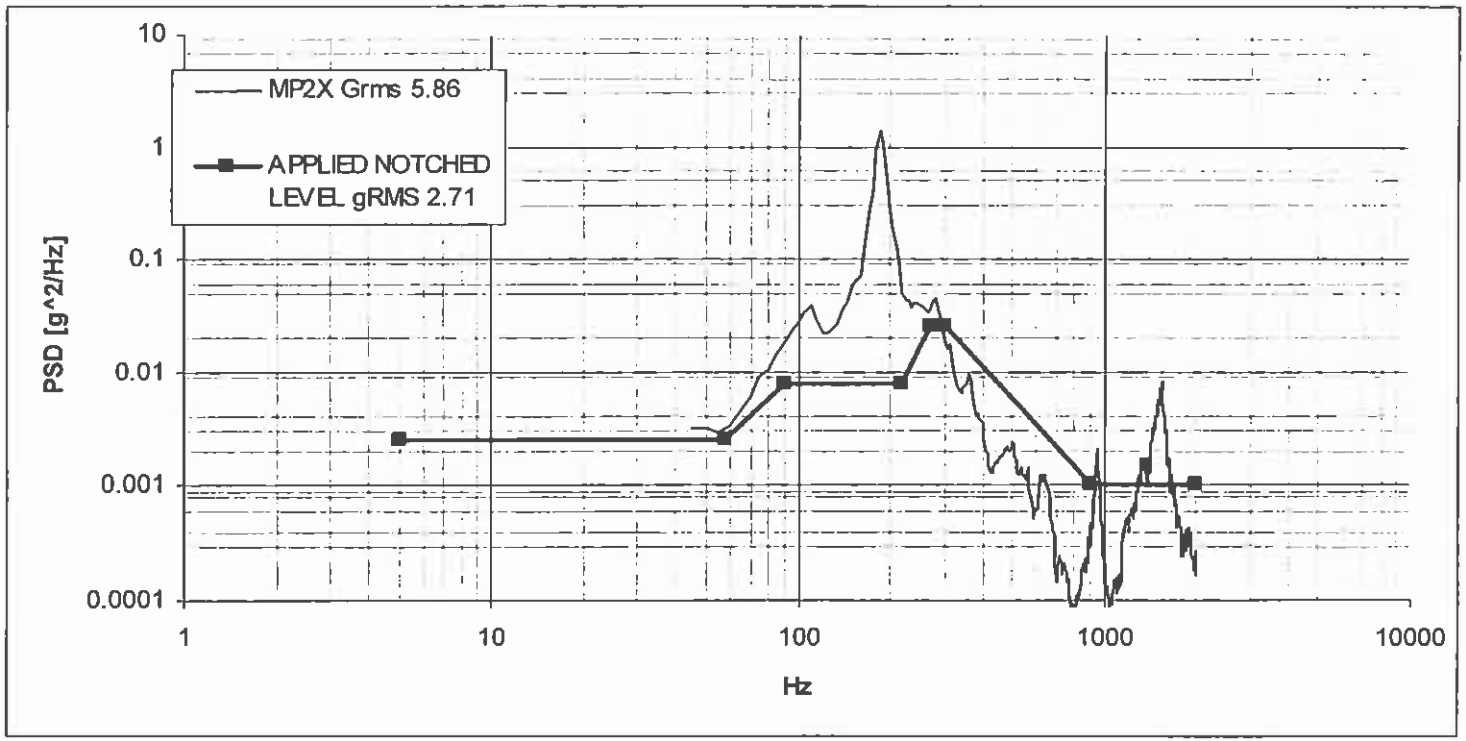
X DIRECTION TEST RESULTS: DYNAMIC RESPONSE

The following plot shows the RICH structure response (CoG representative)



X DIRECTION TEST RESULTS: DYNAMIC RESPONSE

The following plot show the grids highest dynamic response



RICH RVT X CONCLUSION

- First Mode > 50Hz
- No structural yielding or failure detected.
- The acceleration limits on PMT, CoG and reflector have been guaranteed

Y DIRECTION TEST RESULTS: MODAL BEHAVIOUR

MAIN MODE : 95 Hz

RICH DETAILED BEHAVIOUR:

GRIDS:
TWO PEAKS @ f1=110 Hz and f2=190 Hz
AMPLIFICATIONS RANGE FROM 6 TO 10.

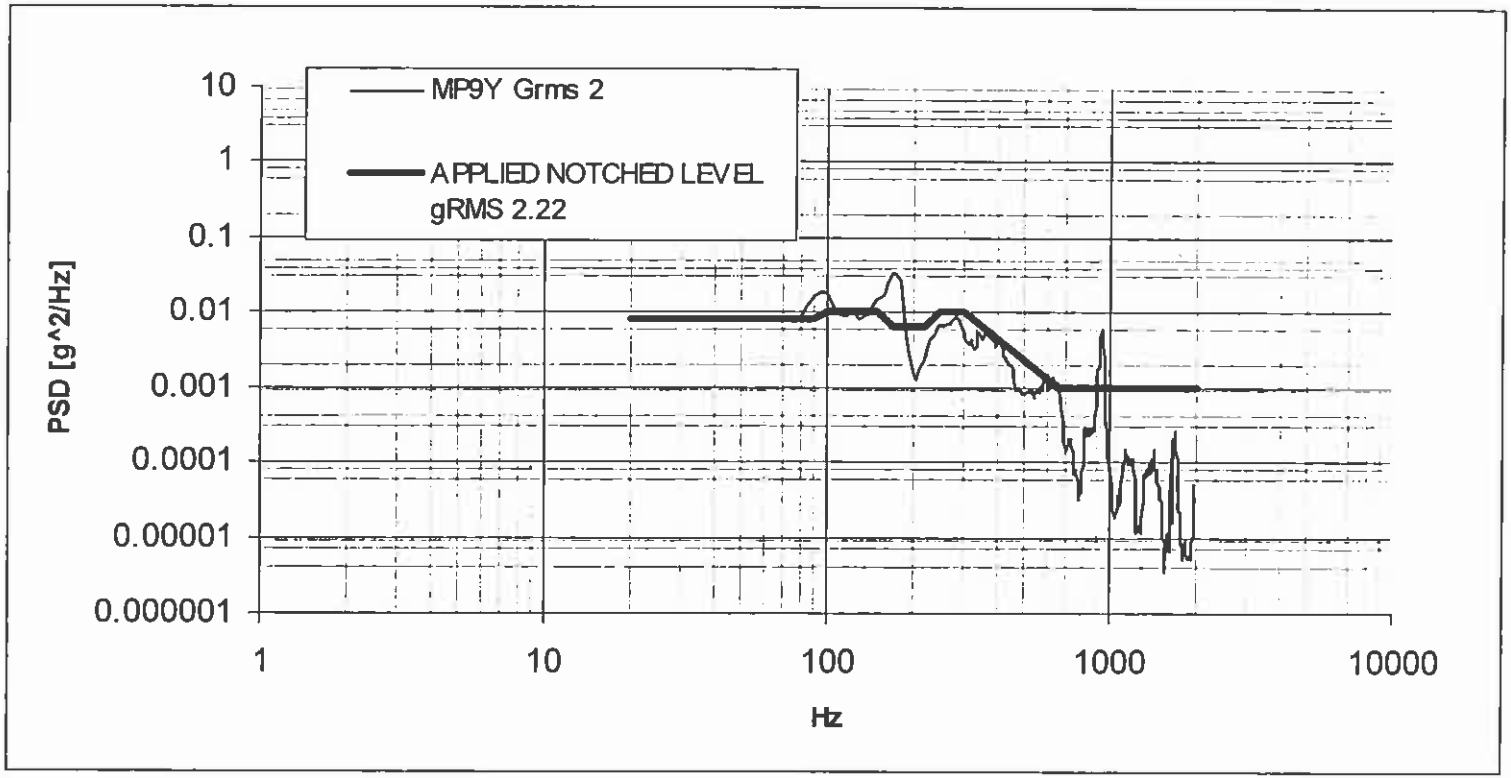
STRUCTURE:
TWO PEAKS @ f1=95 Hz and f2=175 Hz
AMPLIFICATIONS RANGE FROM 4 TO 13.

REFLECTOR:
FIRST MODE IS @ f1=34 Hz
AMPLIFICATIONS RANGE FROM 4 AND 13.

DEBRIS SHIELD:
TWO PEAKS @ f1=80 Hz and f2=105 Hz

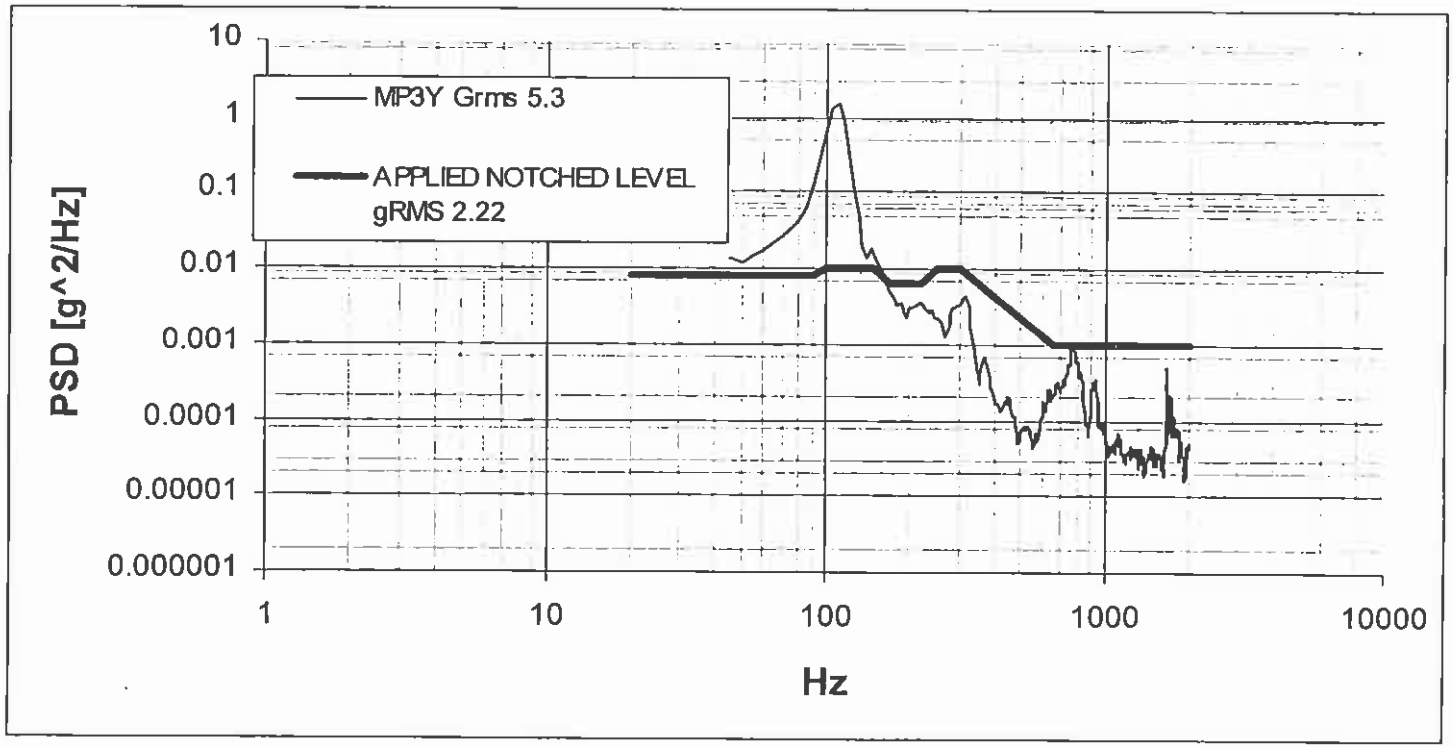
Y DIRECTION TEST RESULTS: DYNAMIC RESPONSE

The following plot shows the RICH structure response (CoG representative)



Y DIRECTION TEST RESULTS: DYNAMIC RESPONSE

The following plot show the grids highest dynamic response



RICH RVT Y CONCLUSION

- First Mode > 50Hz
- No structural yielding or failure detected.
- The acceleration limits on PMT, CoG and reflector have been guaranteed

Z DIRECTION TEST RESULTS: MODAL BEHAVIOUR

MAIN MODE : 100 Hz

RICH DETAILED BEHAVIOUR:

GRIDS:
TWO PEAKS @ f1=100 Hz and f2=211 Hz
AMPLIFICATIONS RANGE FROM 3 TO 28 (ON FIRST PEAK).

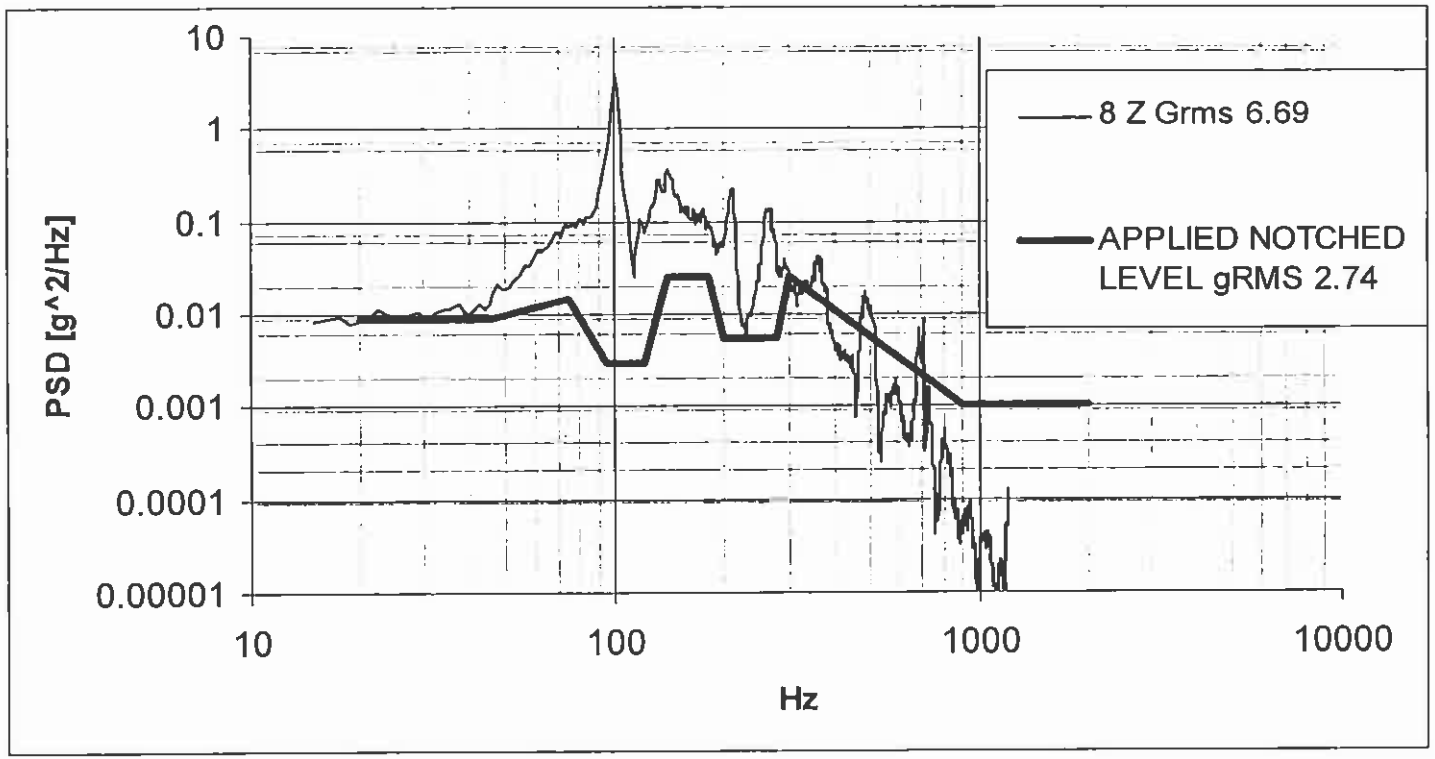
STRUCTURE:
TWO PEAKS @ f1=100 Hz and f2=211 Hz
AMPLIFICATIONS RANGE FROM 6 TO 36

REFLECTOR:
FIRST MAIN MODE IS @ f1=105 Hz
AMPLIFICATIONS RANGE FROM 4 AND 13.

DEBRIS SHIELD:
THREE PEAKS @ f1= 80 Hz, f2=110 Hz and f3=290 Hz

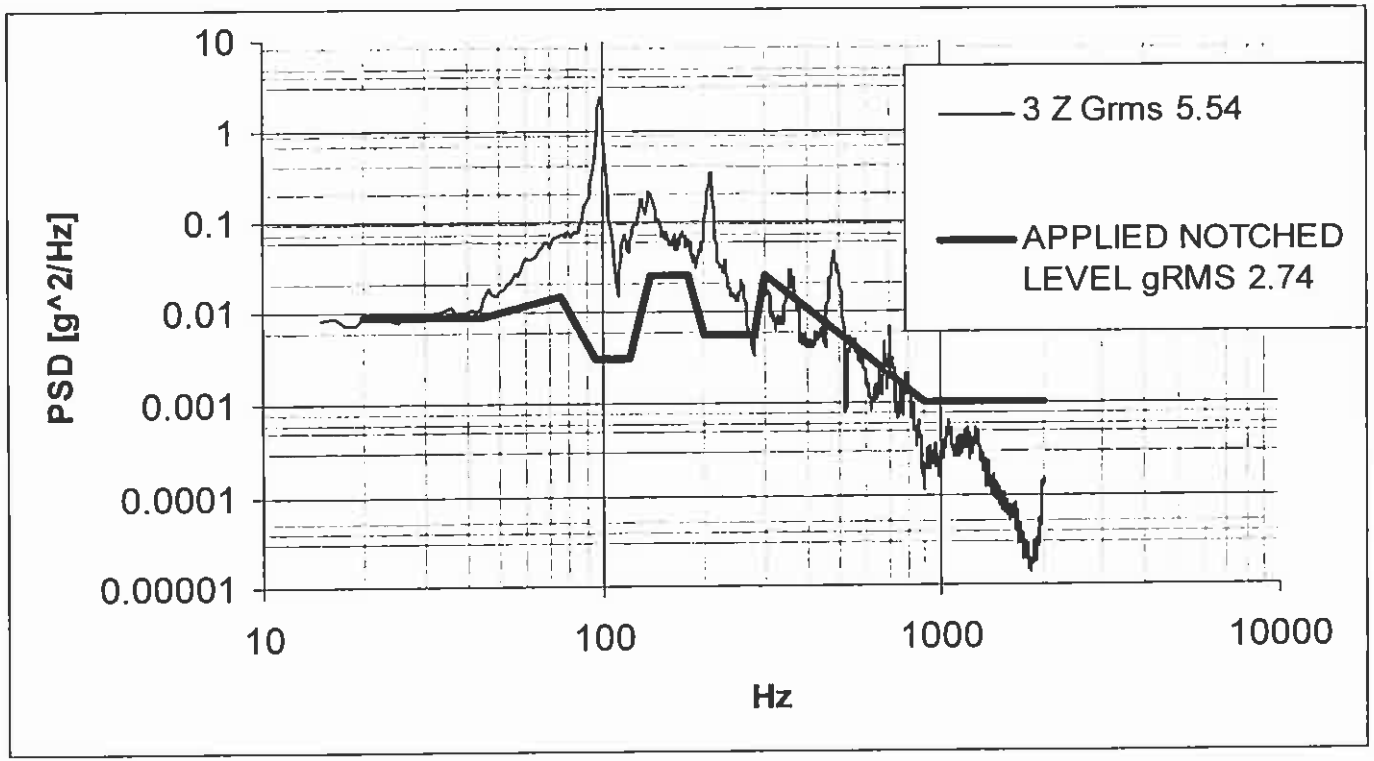
Z DIRECTION TEST RESULTS: DYNAMIC RESPONSE

The following plot show the RICH structure response (CoG representative)



Z DIRECTION TEST RESULTS: DYNAMIC RESPONSE

The following plot show the grids highest dynamic response



RICH RVT Z CONCLUSION

- First Mode > 50Hz
- No structural yielding or failure detected.
- The acceleration limits on PMT, CoG and reflector have been guaranteed

ISSUED NCR

An NCR (NCR-RICHSYS-CGS-C-020 Rev.3) was opened during the Z direction random vibration test (18-19/10/2007) since it has been noticed that the response of some unit measurements points of the PMTs grids were higher than predicted. In order to preserve the Unit Under Test and to perform additional investigation the test has been stopped.

The investigation result was reported in the NCR and the conclusion was that the test setup was the responsible of the higher amplification than the prediction; in particular the input at RICH interface was higher than the desired one. By increasing the control point number (from 2 to 4 CPs) the input was well controlled and the unexpected amplifications have been eliminated.

An additional NCR result was an updated notching strategy for the RICH PMTs. In particular the used acceptable maximum g_{RMS} level on lower skin was 6.8 grms. .

The Z direction random vibration test was resumed (10-13/12/2007) and applying the control setup improvement (described in NCR) it has been concluded successfully.

For this reason the NCR is considered closed from CGS and INFN sides pending ASI concurrence.

RVT OVERALL CONCLUSION

- The rich first mode in each direction is > 50 Hz

- The applicable vibration environment was applied successfully:
  - No structural yielding or failure detected.
  - No PMT's functional degradation detected after test

- The test is considered successfully completed.