New Folder Name STACKS NOTEBOOKS

FILE: T920030

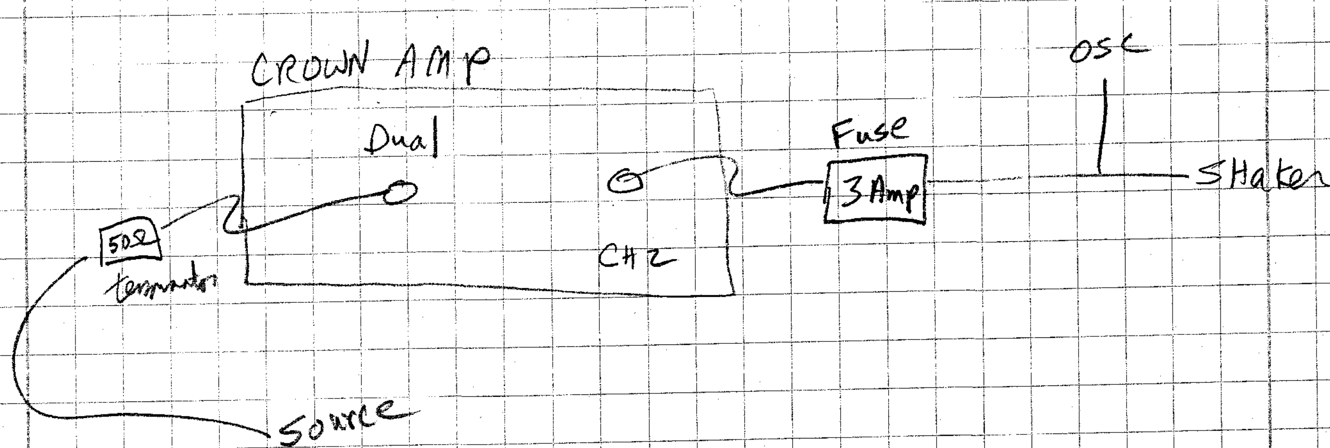
BATCH START

STACKS BOOK1

STAPLE
OR
DIVIDER

Oct 17, 1992

Tests for measuring resonances of support structure



① Had to use channel 2 + dual since had grounding problems when looked at channel 1

② Used 50 Ω terminator so that 60 Hertz wouldn't drive shaker when source was off

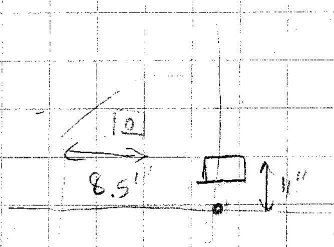
(terminator lowers source voltage by a factor of 2 since FFT has a 50 Ω internal impedance

- source level initially set at 50 mV_{rms} (full gain)
- this gave output to shaker of $5\,V_{peak\text{-}p} \Rightarrow \frac{2.5}{\sqrt{2}}$ vrms
- if assume 1 Ω resistance of shaker ~ $\frac{2.5}{\sqrt{2}}$ amps all during shaker

- changed source level to 100 mV_{rms} (full gain)
- voltage to shaker is 14.5 V_{pk} = $\frac{7.25A}{\sqrt{2}}$ = 5.6 A_{rms} R_{SH} = 1

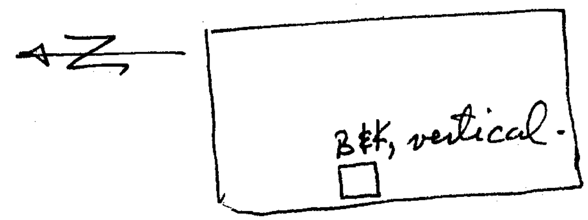
3 Amp fuse did not break

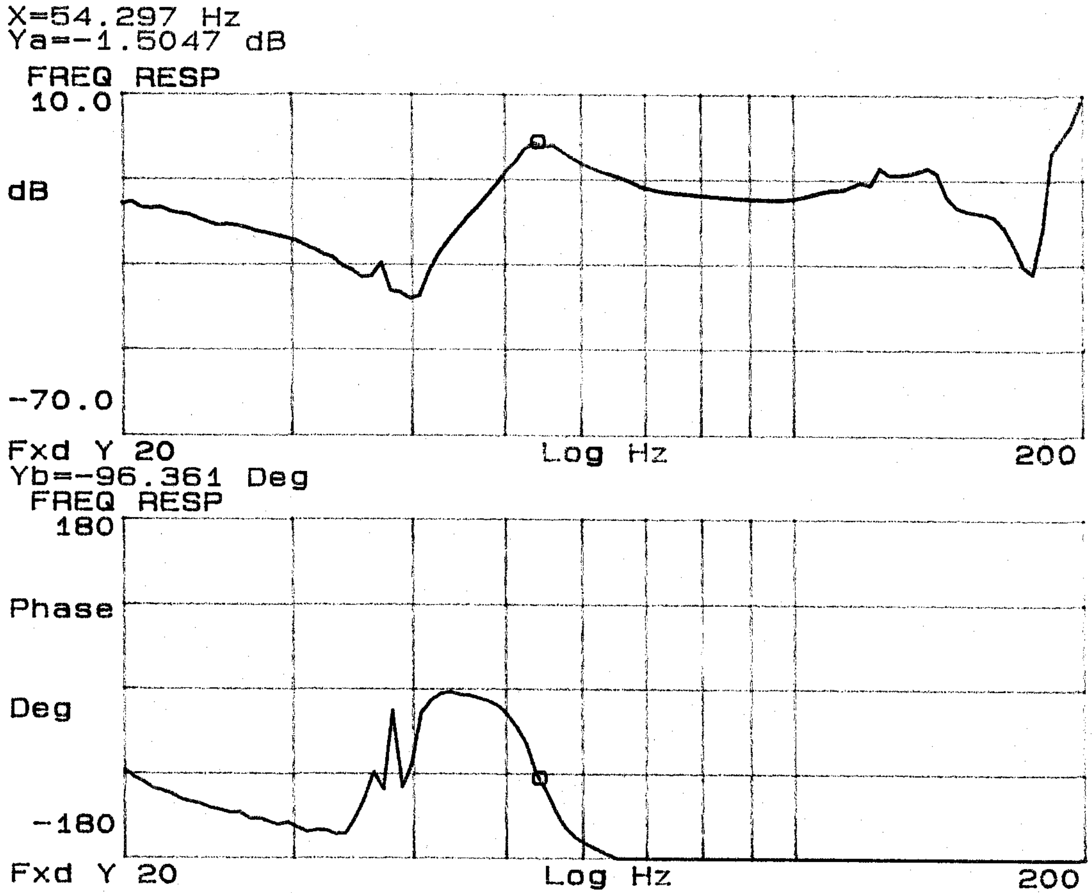
Believe $R_{SH} \sim 2$ ⇒ I_{SH} = 2.8 A_{rms}



16:00

Drive current - to - cable x-fer function



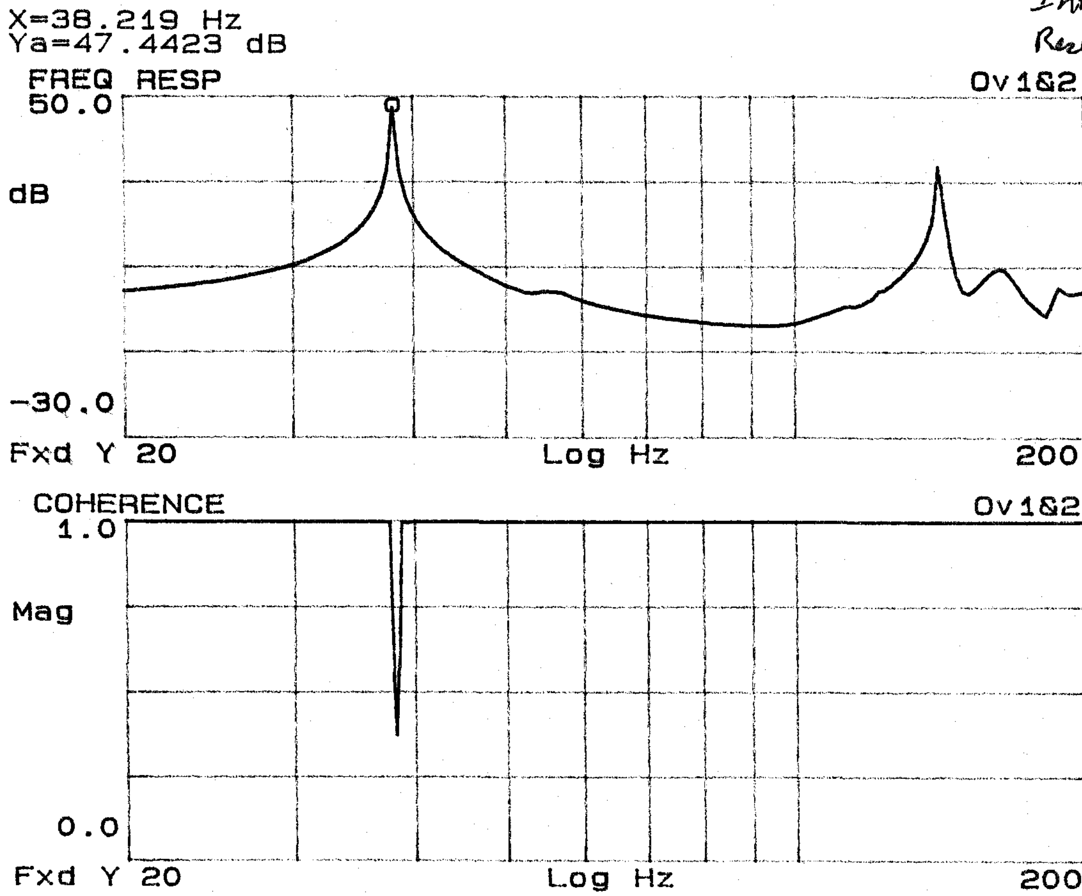


Oct 7, 1992
6:00 PM

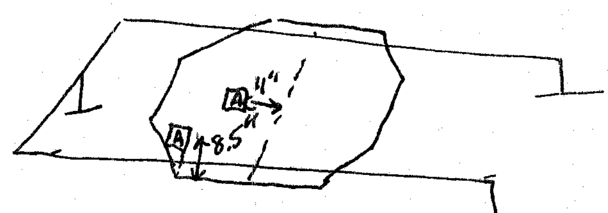
Transfer Fctn from shaker table to top of support plate (unloaded): Vertical to Vertical

Disk: Lisa-STACK TEST
File: Sup

Source Level = 100 mV rms
Amp Gain (Crown) = 8
Avg = 5
Integ time = 500 msec - 2 sec
Resln = 160 pt/dec



- Shaker was shaking vertically
- 1 accelerometer on top plate
- 1 accelerometer on shaker table
- Believe peaks above 100 Hz are acoustic coupling



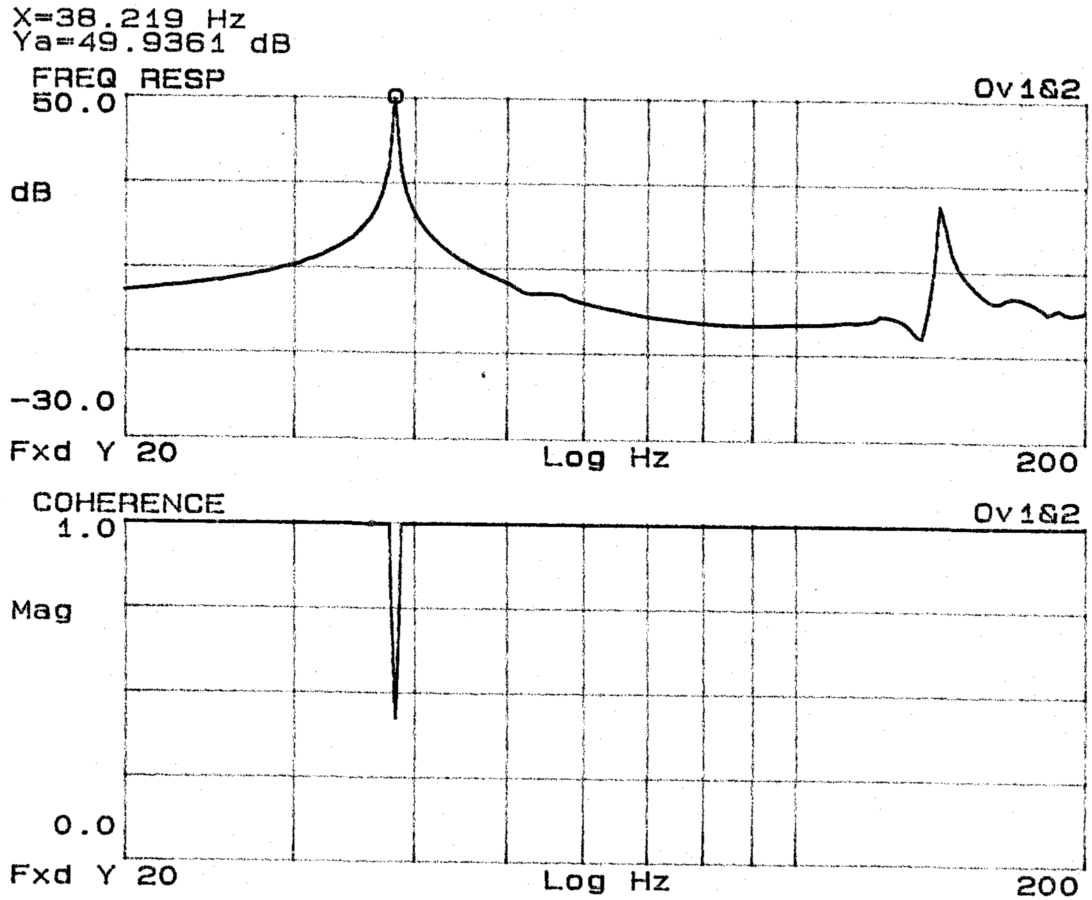
Accel on top plate was 8.5" from edge
Accel on shaker table was 11" from center

Oct 7, 1992
6:15 PM

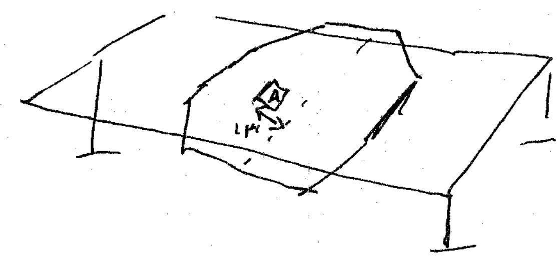
Transfer Fctn from shaker table to top of support plate (unloaded): Vertical to Vertical

Pisk° Lisn - Stack Setup
File: Sup 1

Source Level = 100 mV rms
Amp Gain (Crown) = 8
Avg = 5
Integ time = 500 msec - 2 sec
Resln = 160 pt/dec



- shaker shaking vertically
- 1 accelerometer on center of top plate
- 1 accelerometer on shaker table (11" from center)
- Plot is same as Sup

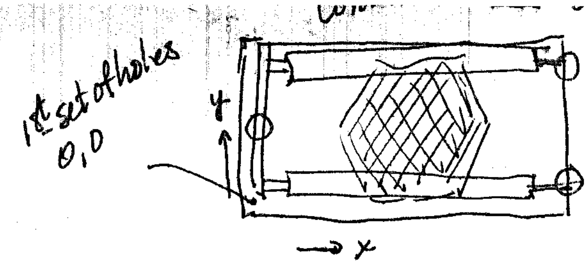


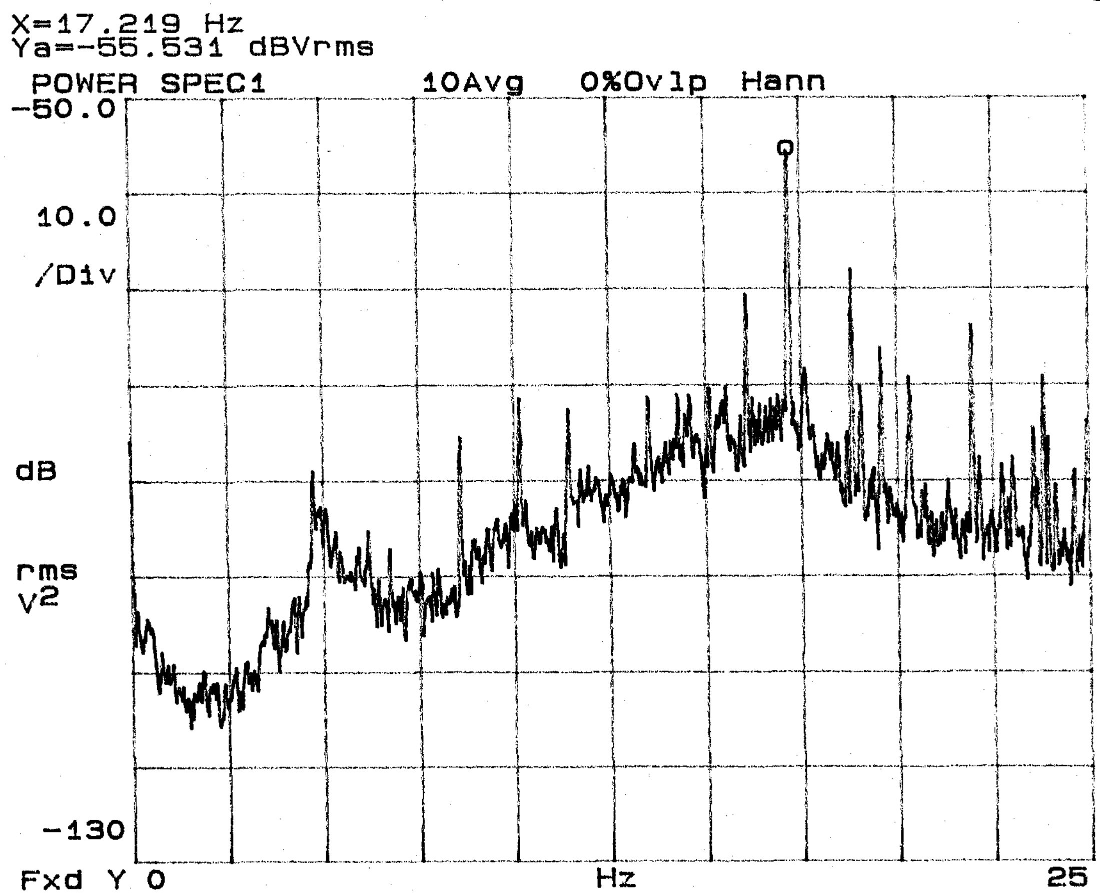
10:20AM.

Powerspectrum

Accelerometer 886910 on Newport table at 18.5", 3.5"

Source - ground noise



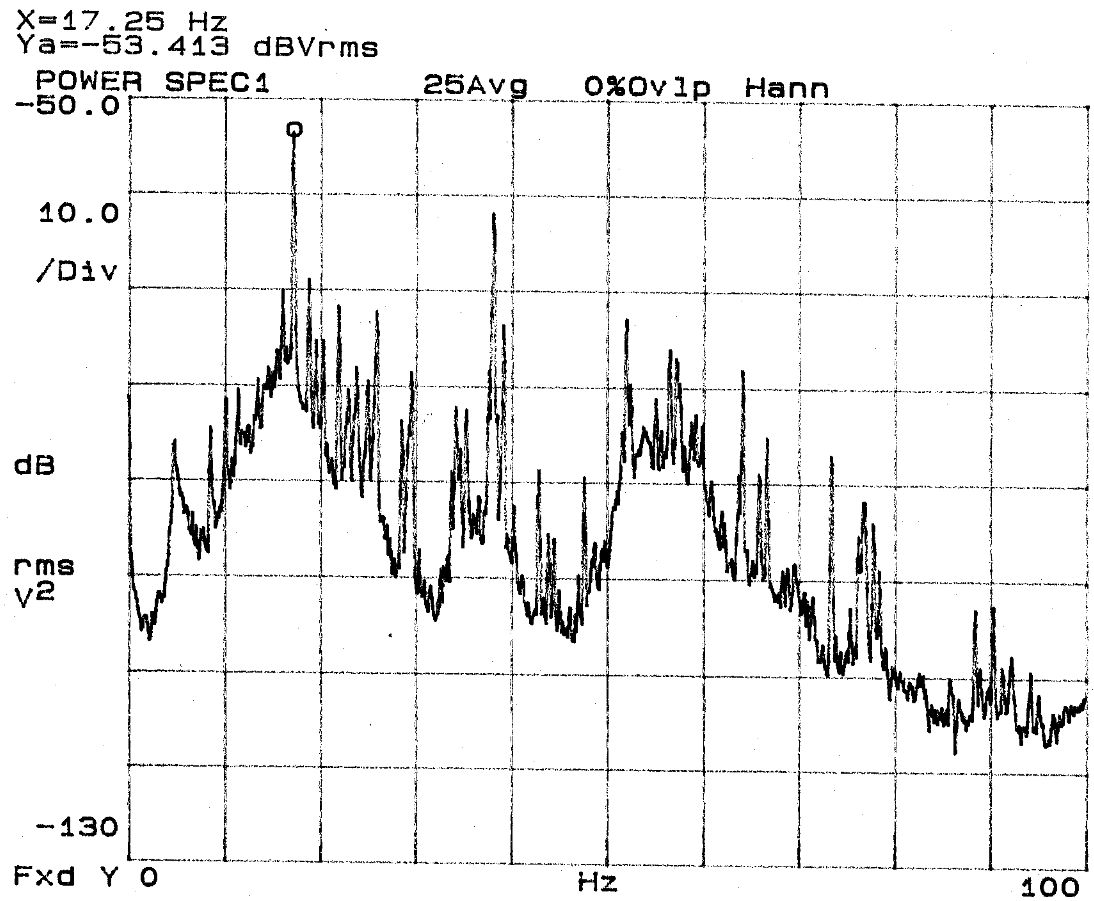


file - 55T

resonance of Newport table and lower support structure on Viton springs ≈ 17 hz

10/12/92.
10:53AM.
file SST 1

Same as previous meas. except. 0-100hz. and average = 25



10/12/92.
11:30 AM.

vertical transfer function

#886909 in center of stack bottom plate

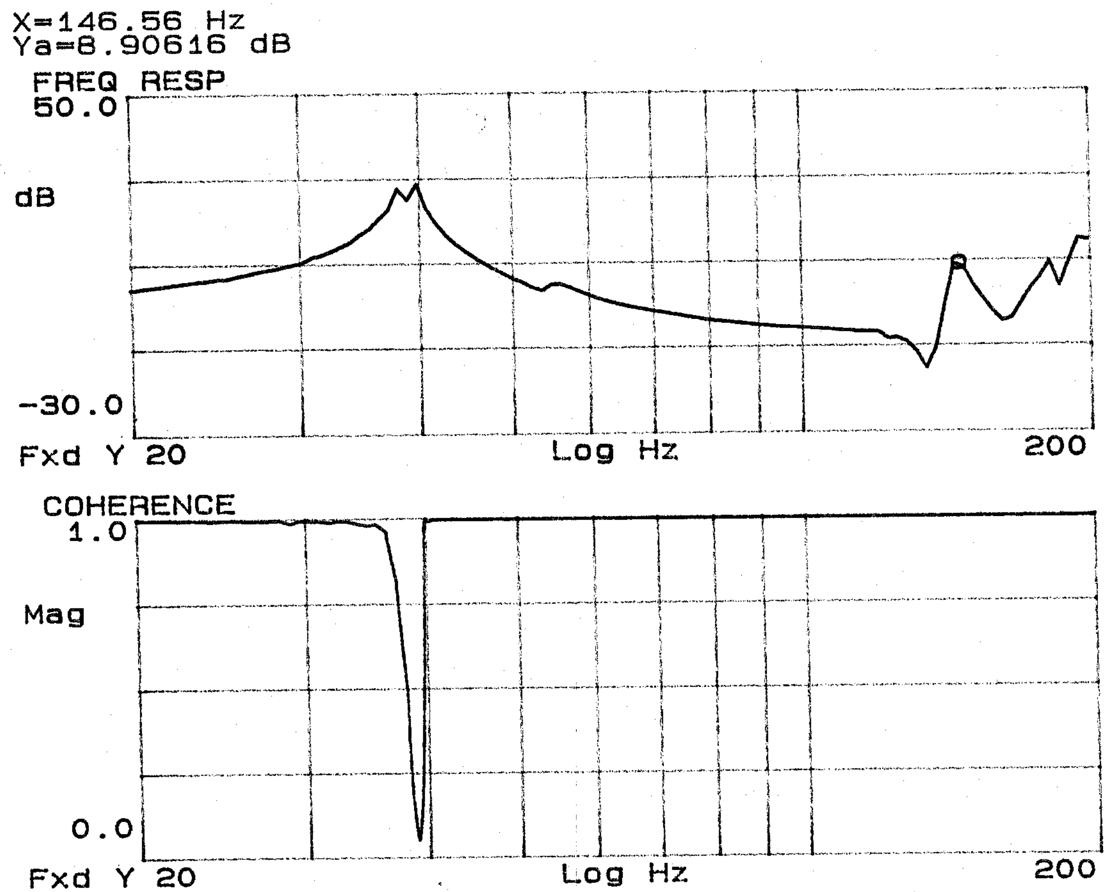
#886910 at cross beam support plate.

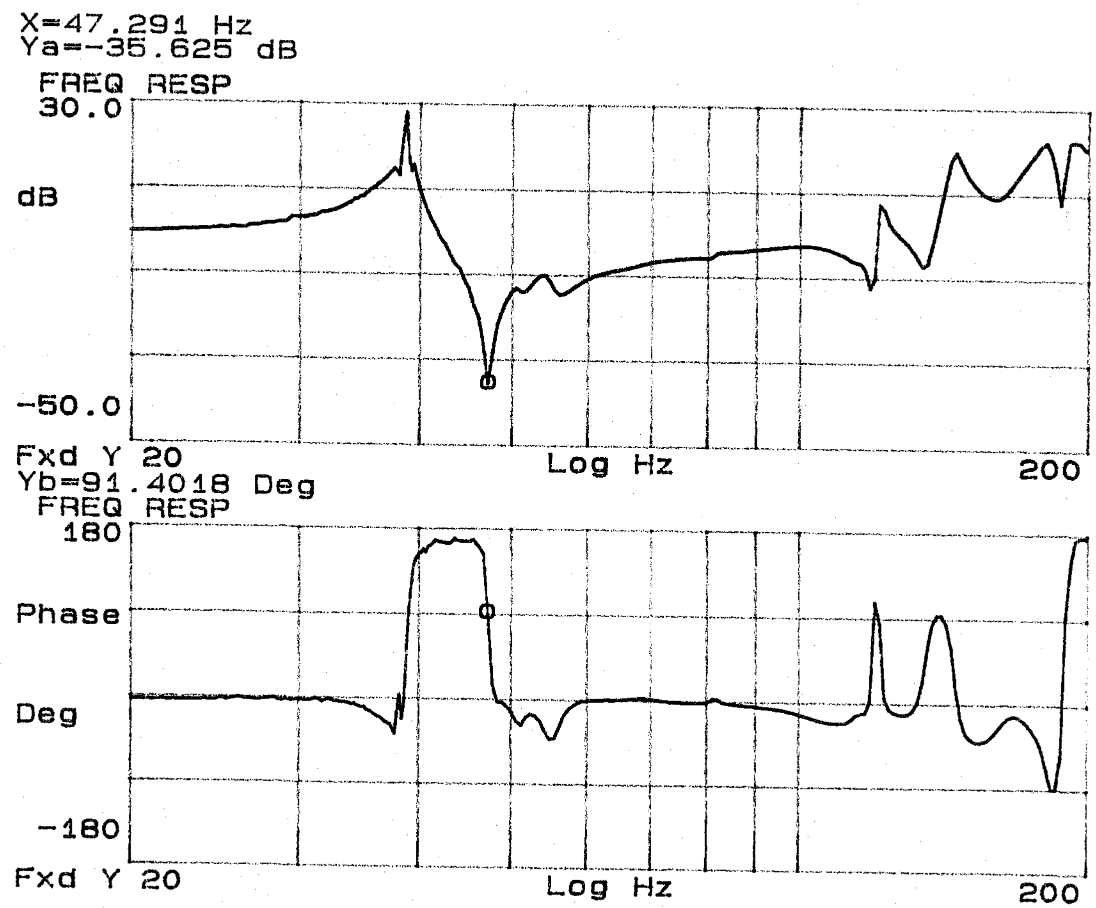
FFT source level 58 mV RMS

CROWN Amp at max. gain

Scope shows ~ 7 Volts peak to peak.

SST2





10/12/92.

1:51 pm.

vertical transfer function (on Newport table) with Acc. 1 at base of cross bar and Acc 2 at corner of cross bar (on crossbar)

file SST3

now rotate shaker to horizontal orientation

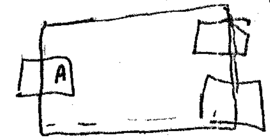
mount Acc 2 in center of stack bottom plate
Acc 1 on base plate for cross bar support

both Accs oriented horizontally E-W as is shaker

2:20 PM

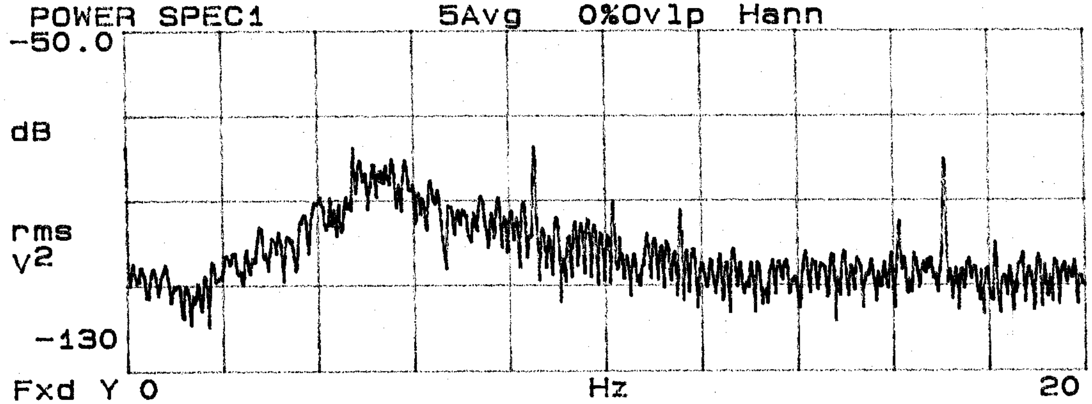
File SST4

- ground noise excited ~~transfer function~~ (~~Horizontal to Horizontal~~ Power Spectrum)
- Bottom accelerometer is taped on support plate in horizontal position

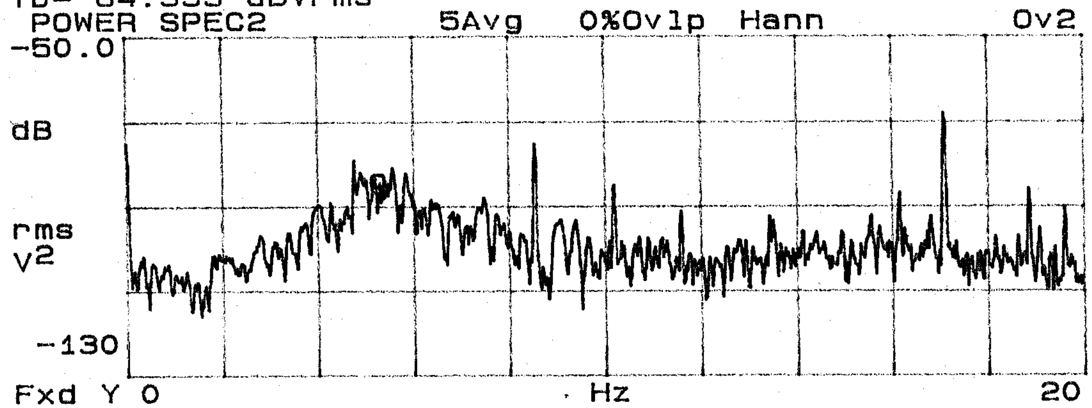


- ~~Top accelerometer on~~ ~~...~~
- 5 averages

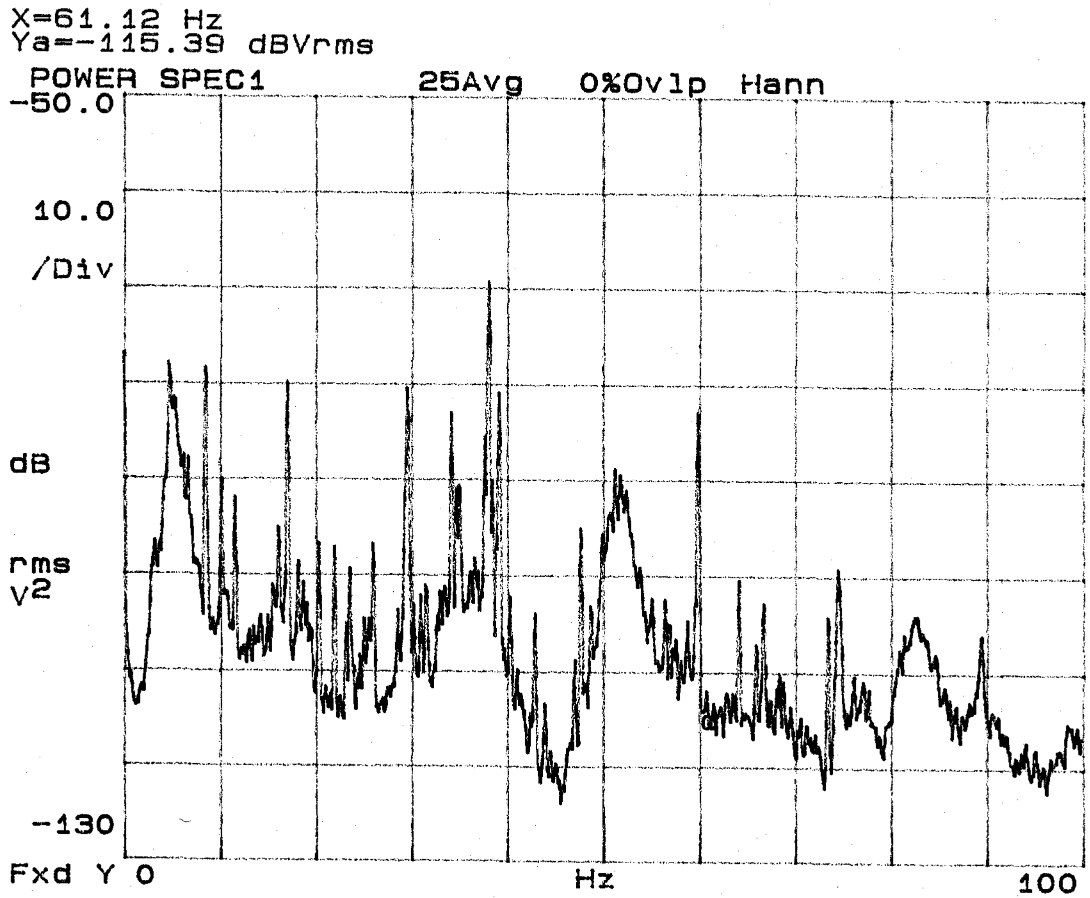
X=5.275 Hz



Yb=-84.355 dBVrms



shows that horizontal resonance of plate + SS on rubber springs is ~ 5.275 Hz

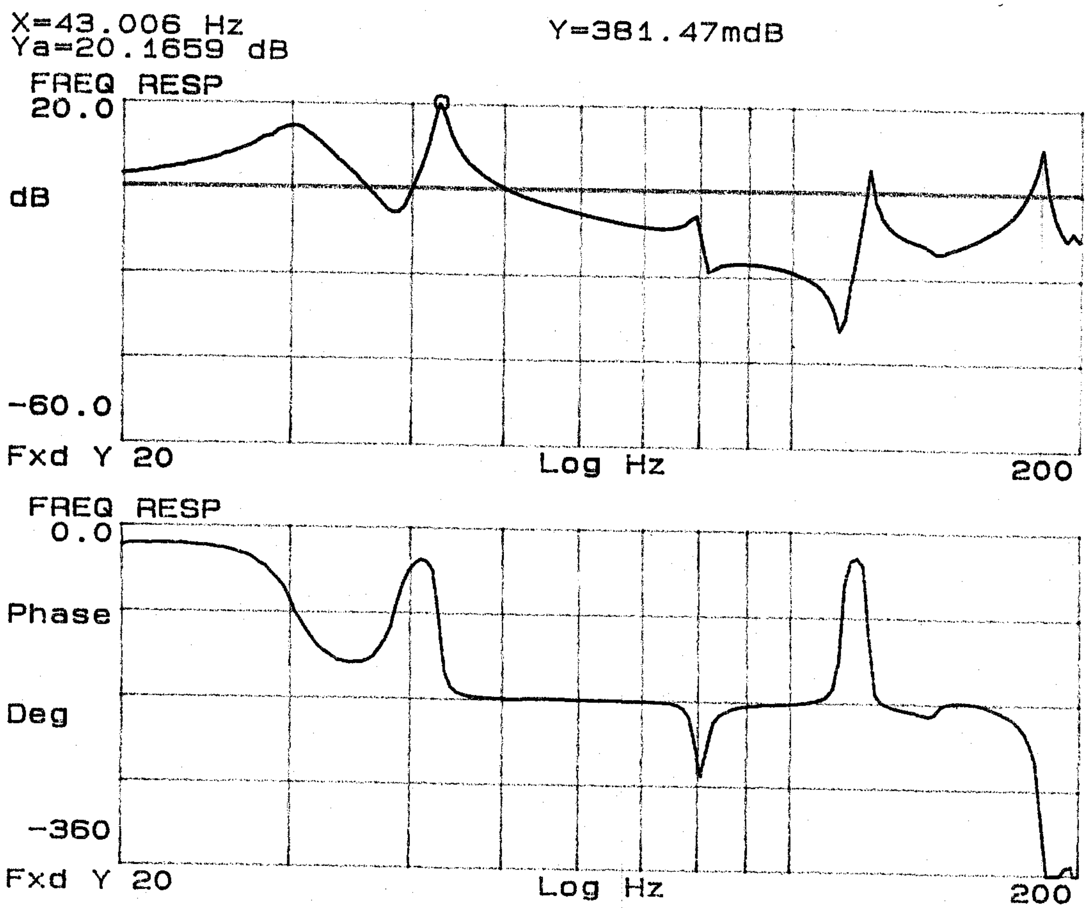


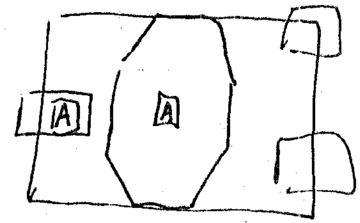
file SST5
horizontal - ground excited
power spectrum Acc 1
in pos. A on prev. plot.

Oct. 12, 1992
3:00 PM
File: SST6

- horizontal to horizontal transfer fctn with shaker excitation

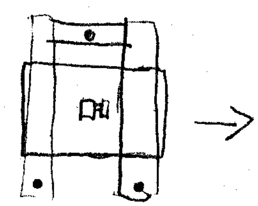
ny=5
rytime = 500 msec
0 pt/dec
source level = 50 mV rms
Il gain on crown



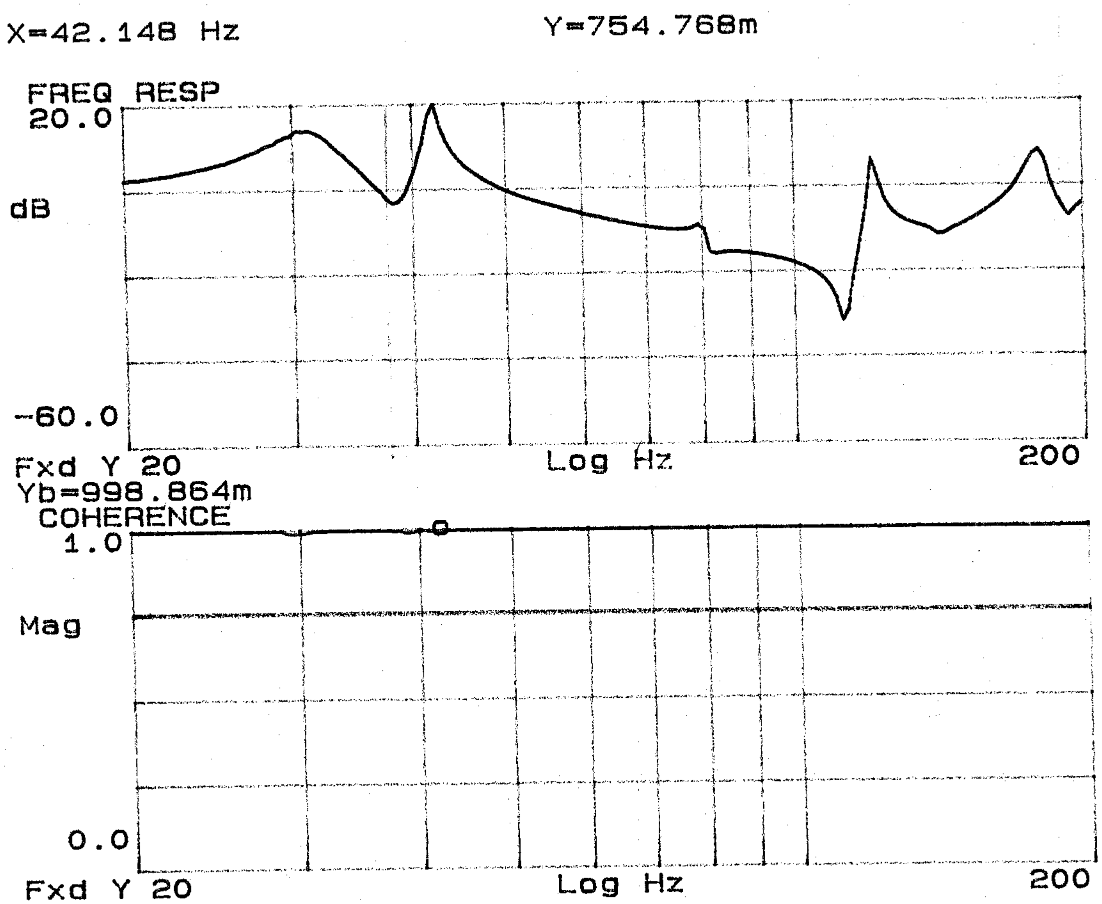


- Top accelerometer on center of plate
- Bottom accelerometer taped on position [A] on support plate bolted to optical table

Shaker drive was: oriented in transverse direction



Oct 12, 1992
3:45 PM

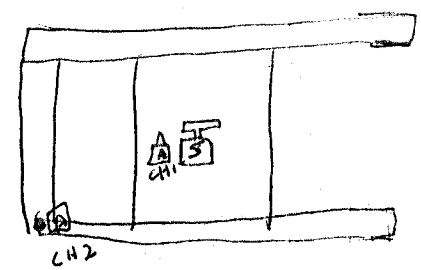


File: SST7

File SST8

- Transfer Function from horizontal to horizontal motion

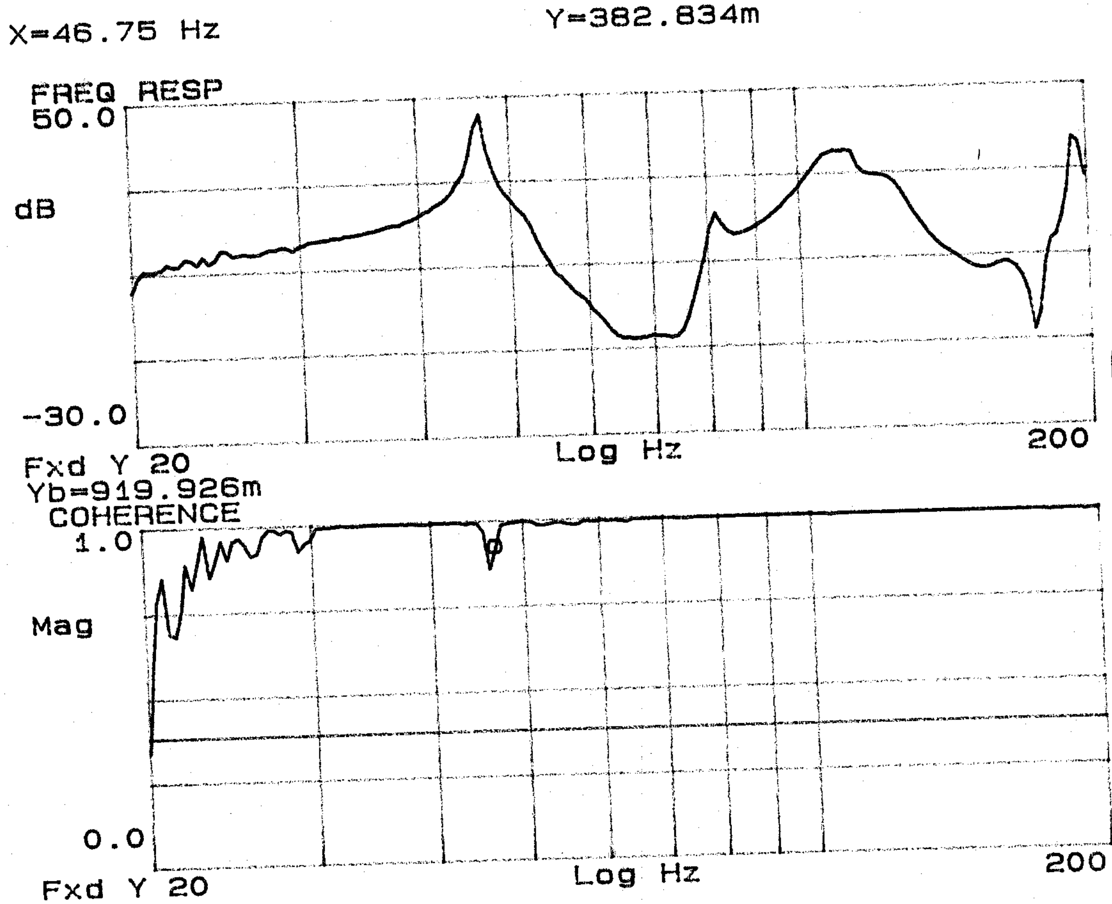
- Same as SST6 but bottom accelerometer was placed close to Shaker



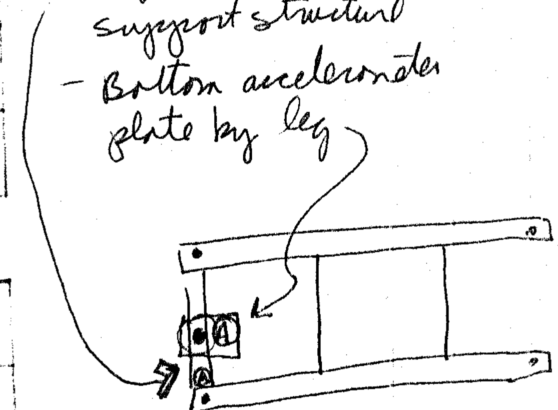
Oct 12, 1992
4:00 PM

SST9

SST10



- Horizontal drive in transverse direction (same as SST7)
- Vertical to vertical transfer fctn
- Top accelerometer at corner of support structure
- Bottom accelerometer plate by leg

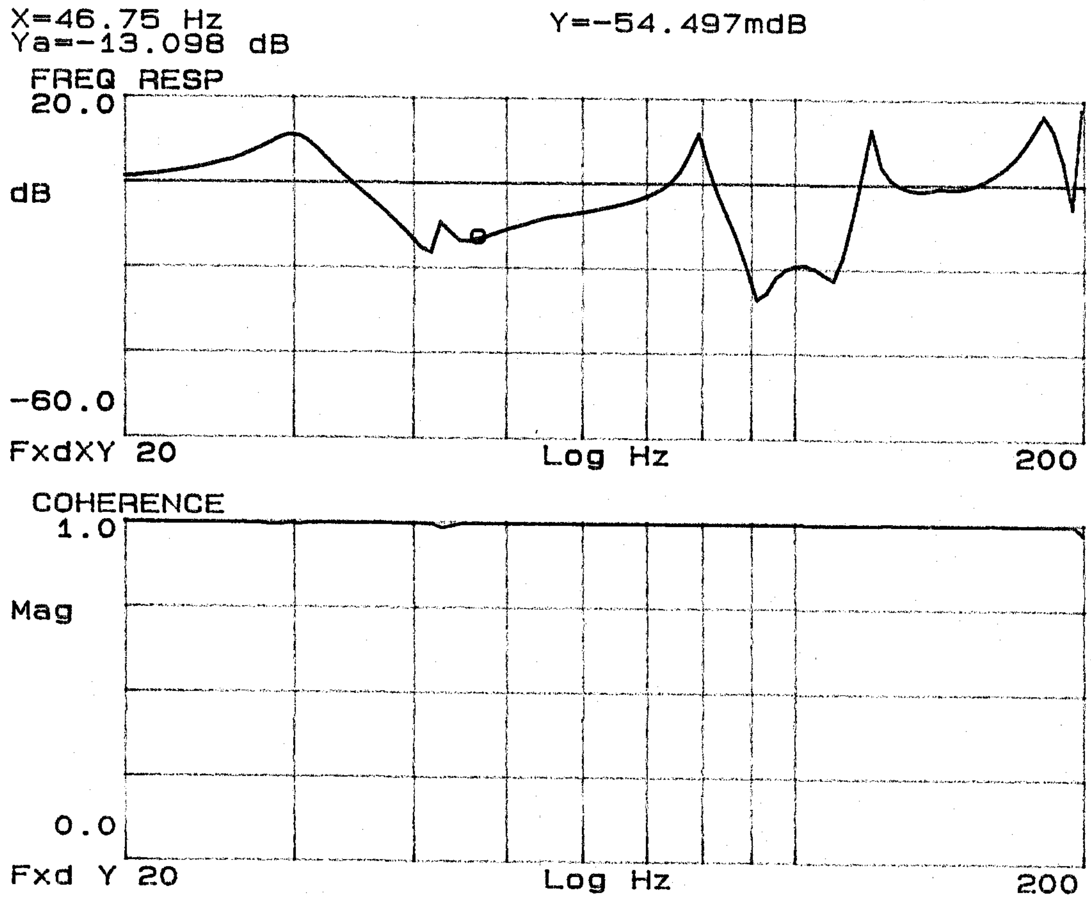


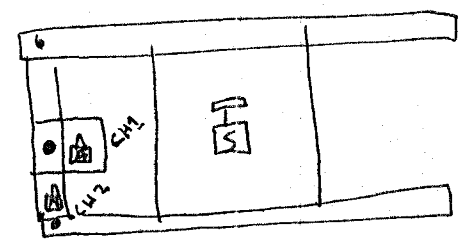
4:45 PM

- Horizontal Drive
- Transfer function from Horizontal to Horizontal

SST11

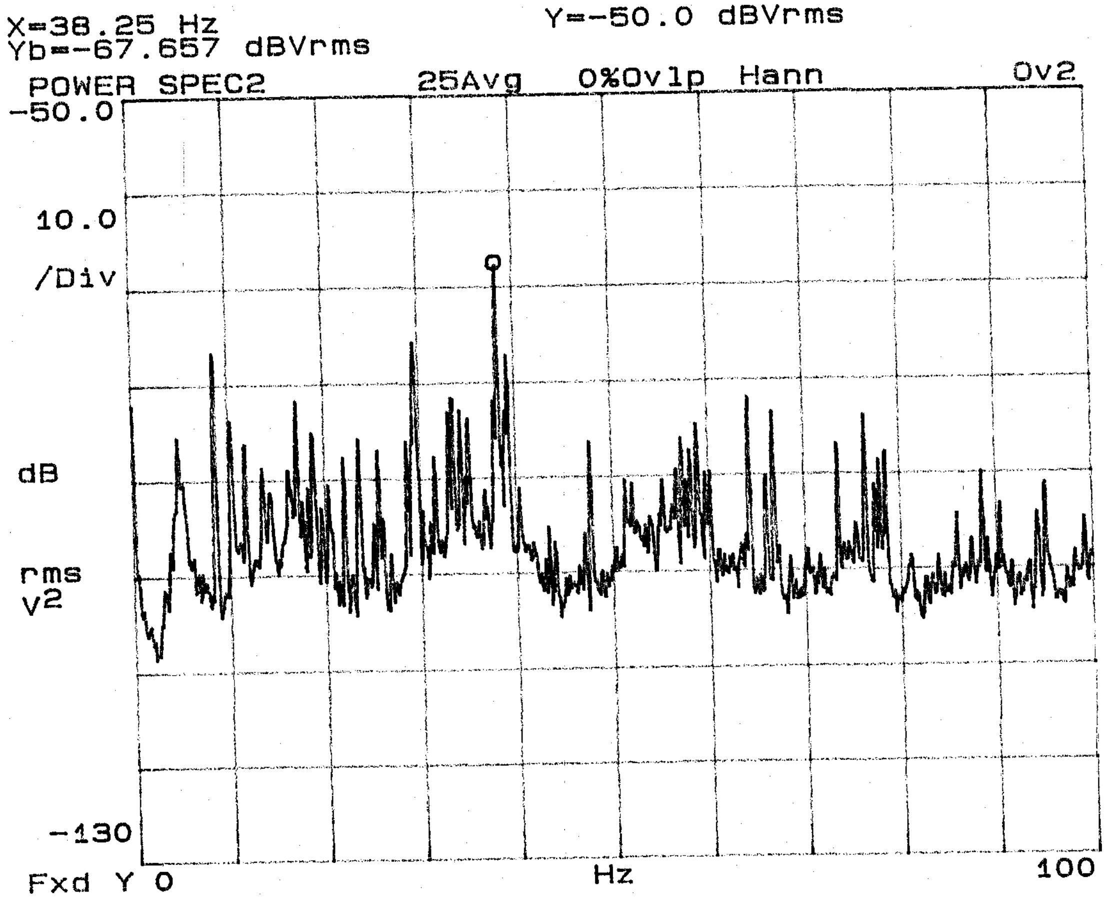
SST12





Oct 12, 1992

Power Spectrum of
Floor in Horizontal Direction



SST13

Door

Structure

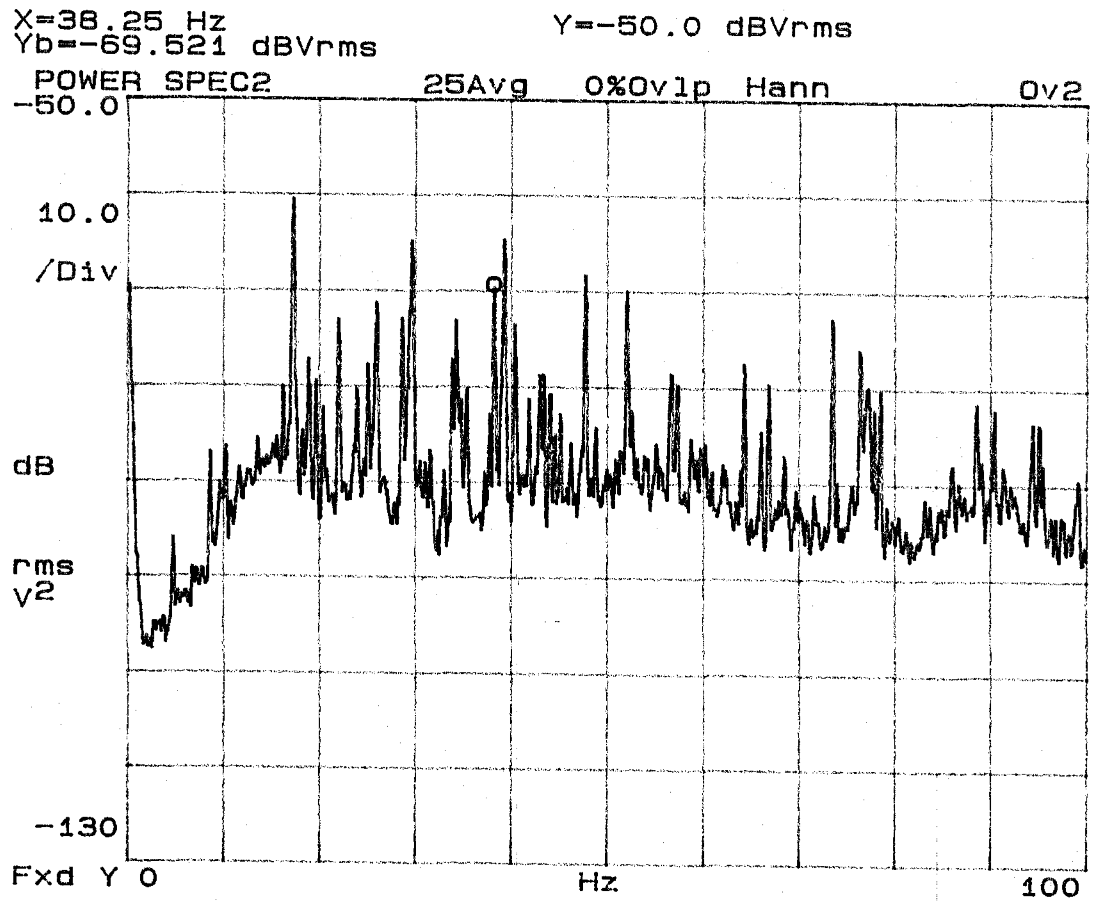
Oct 12, 1992

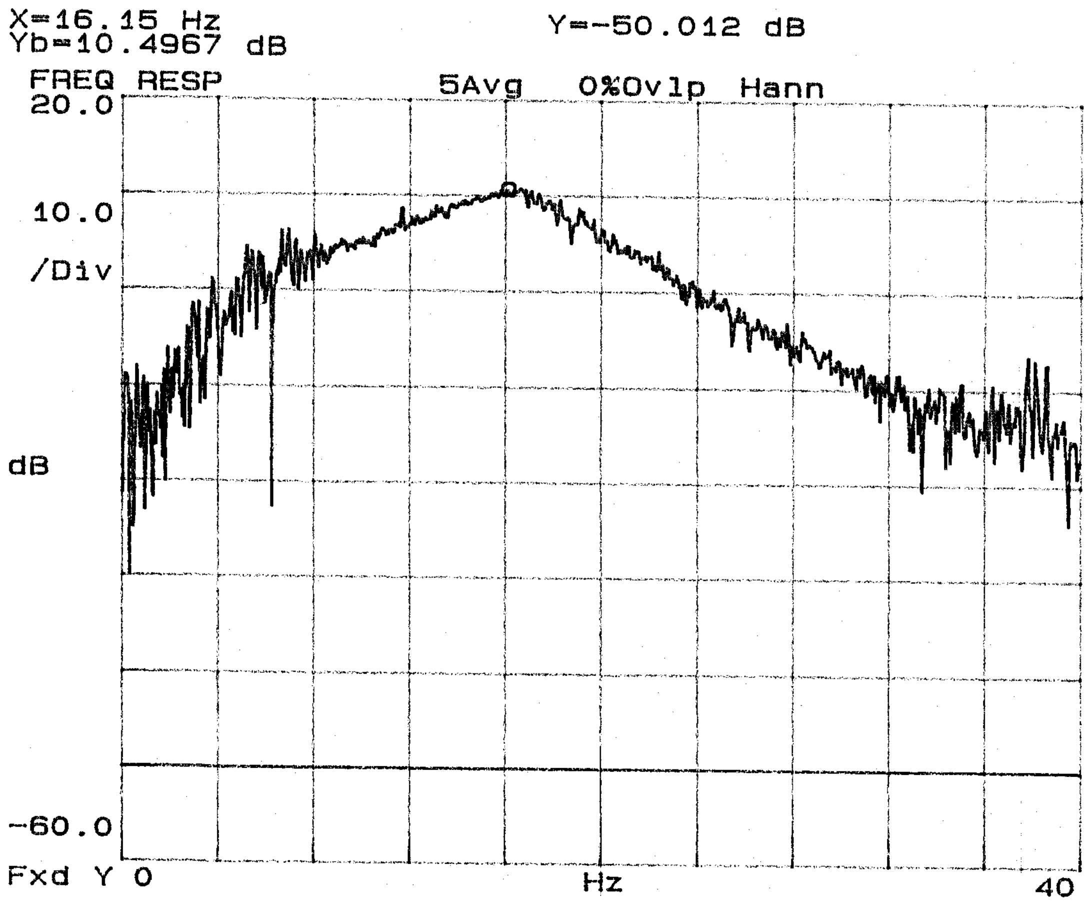
Power Spectrum of Floor in Vertical direction

door

structure

SST14





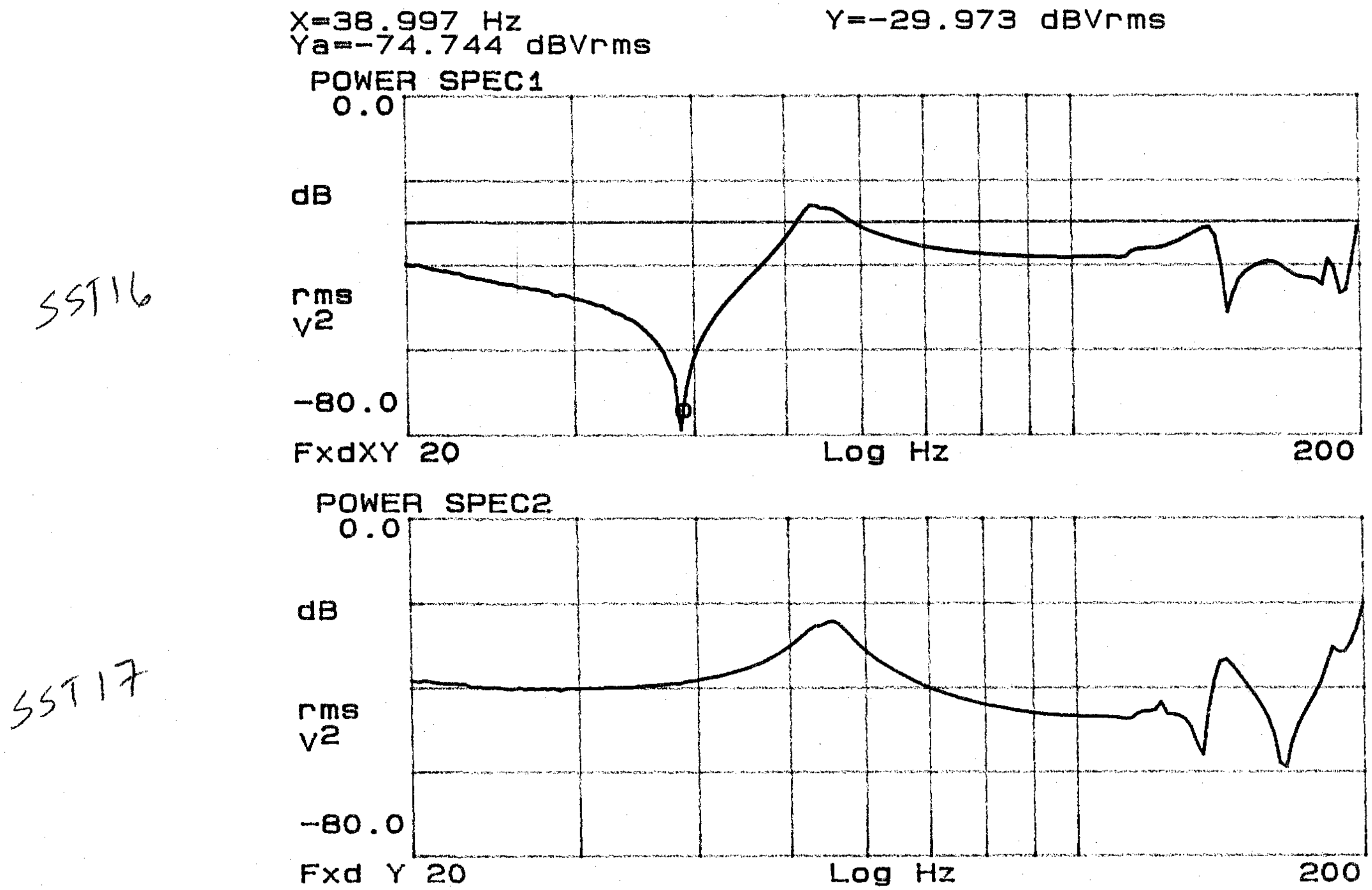
SST15

Transfer fcn from floor to table (optics) in vertical direction using ground noise excitation

Power spectrum of accelerometer ... optics table SST16

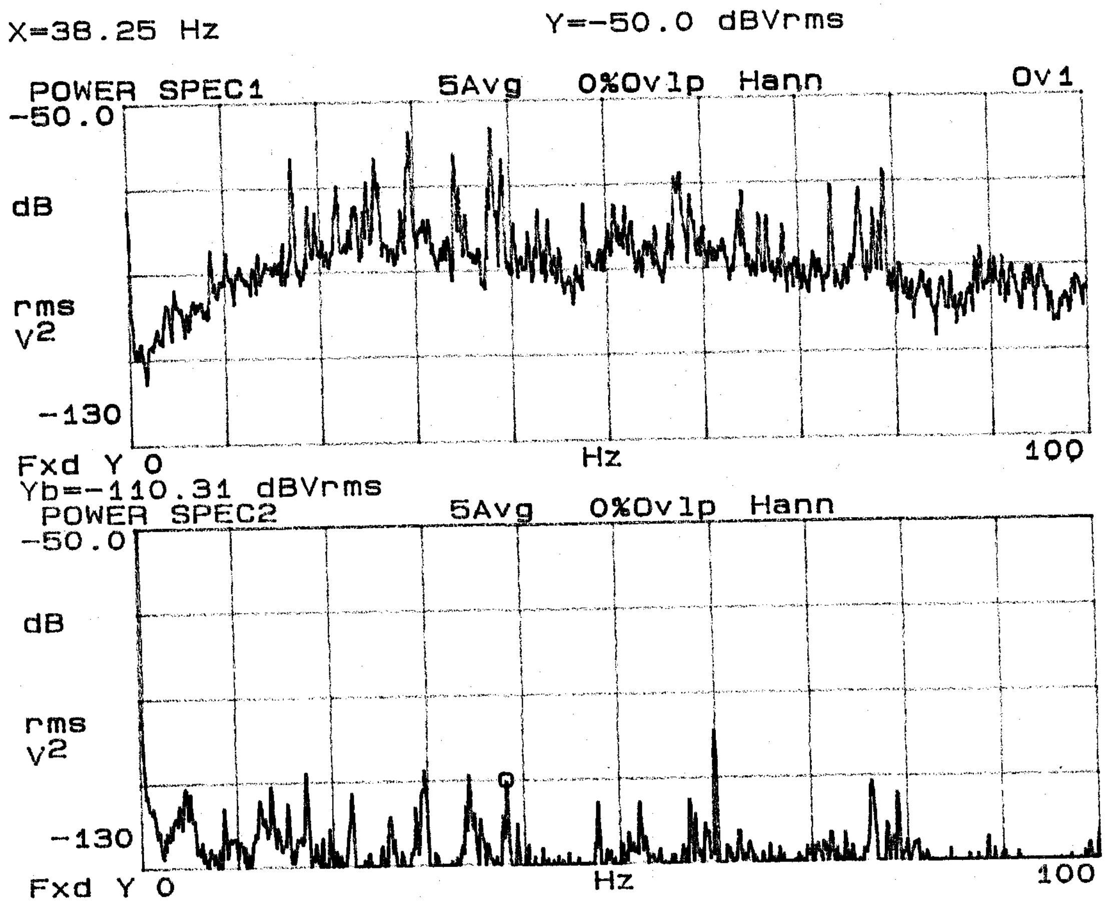
10:30 AM

Driven by shaker



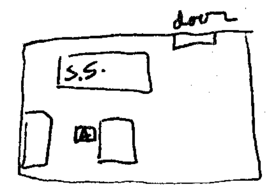
37

Oct 13, 1992
11:30



SST18

Power Spectrum of accelerometer at another floor location.



SST19

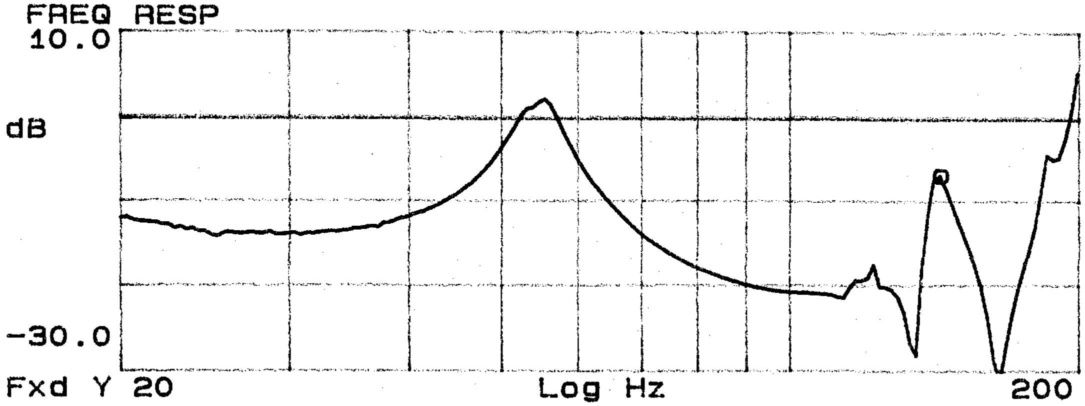
Power Spectrum of speaker in instrument rack

Oct 13, 1992
11:45 AM

X=144.06 Hz
Ya=-7.2459 dB

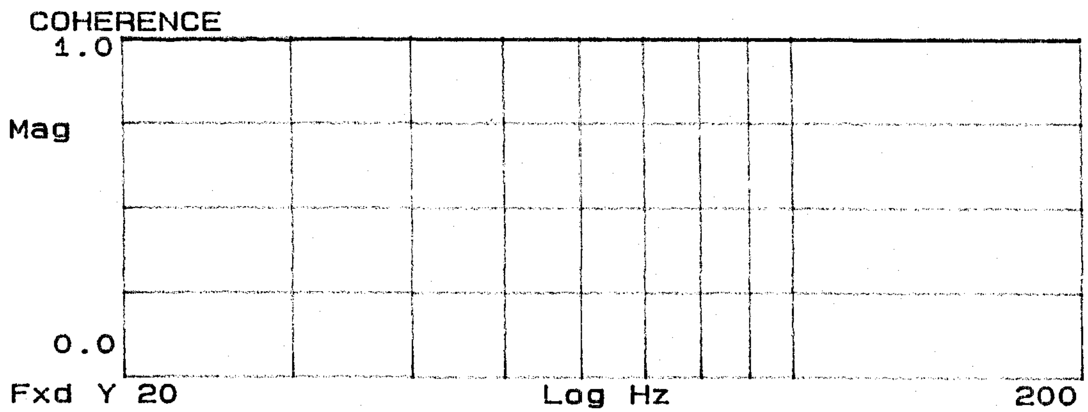
Y=-299.72mdB

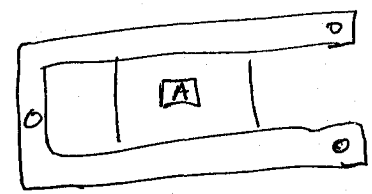
TF



Transfer fctn from Shaker source voltage to voltage of accelerometer on center of support structure in vertical direction

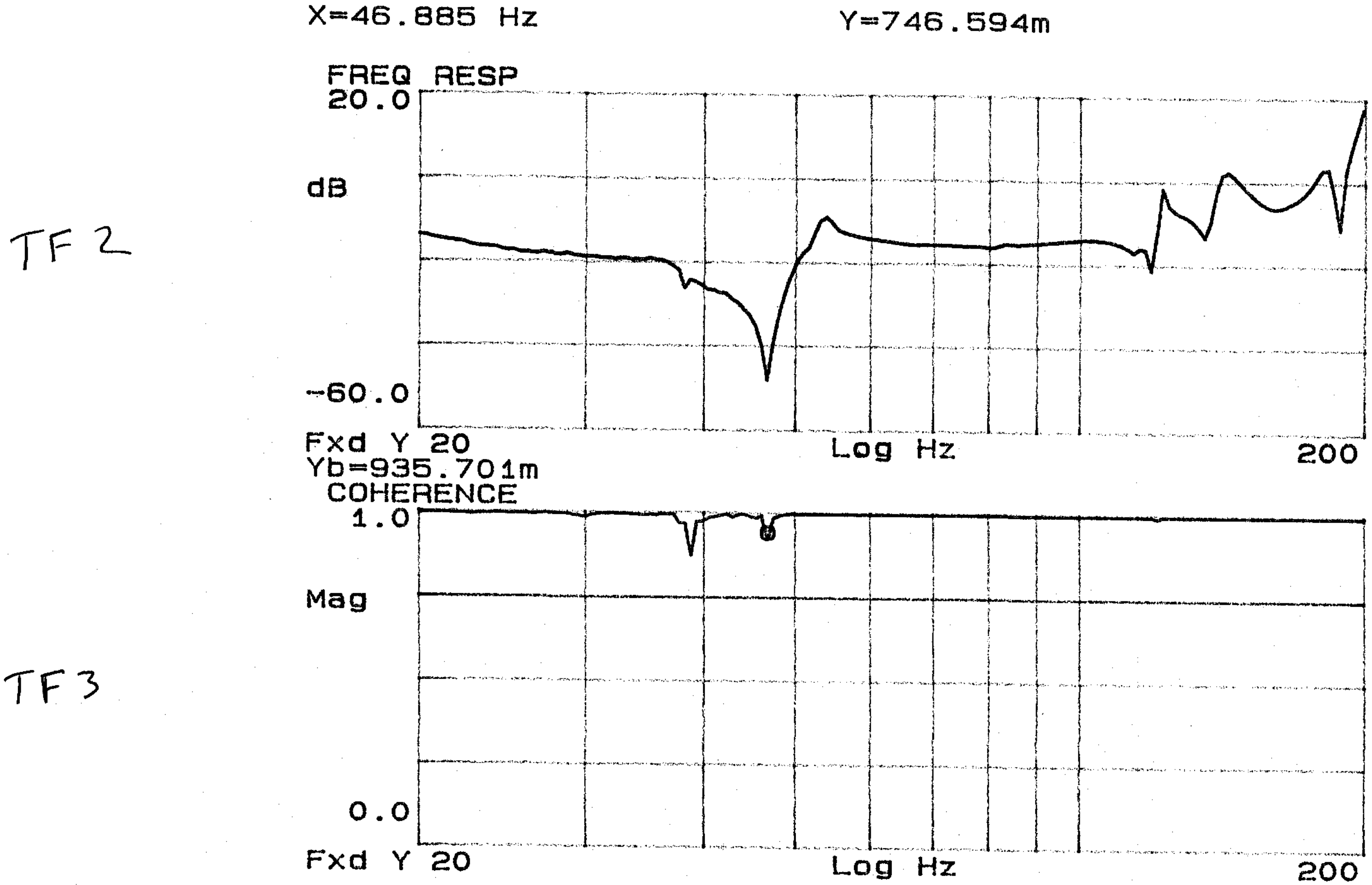
JF1

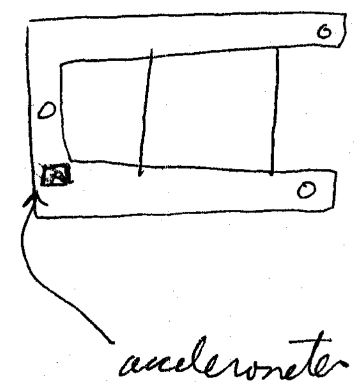




- Transfer Fctn from Vertical shaker voltage to vertical motion on cross-bar

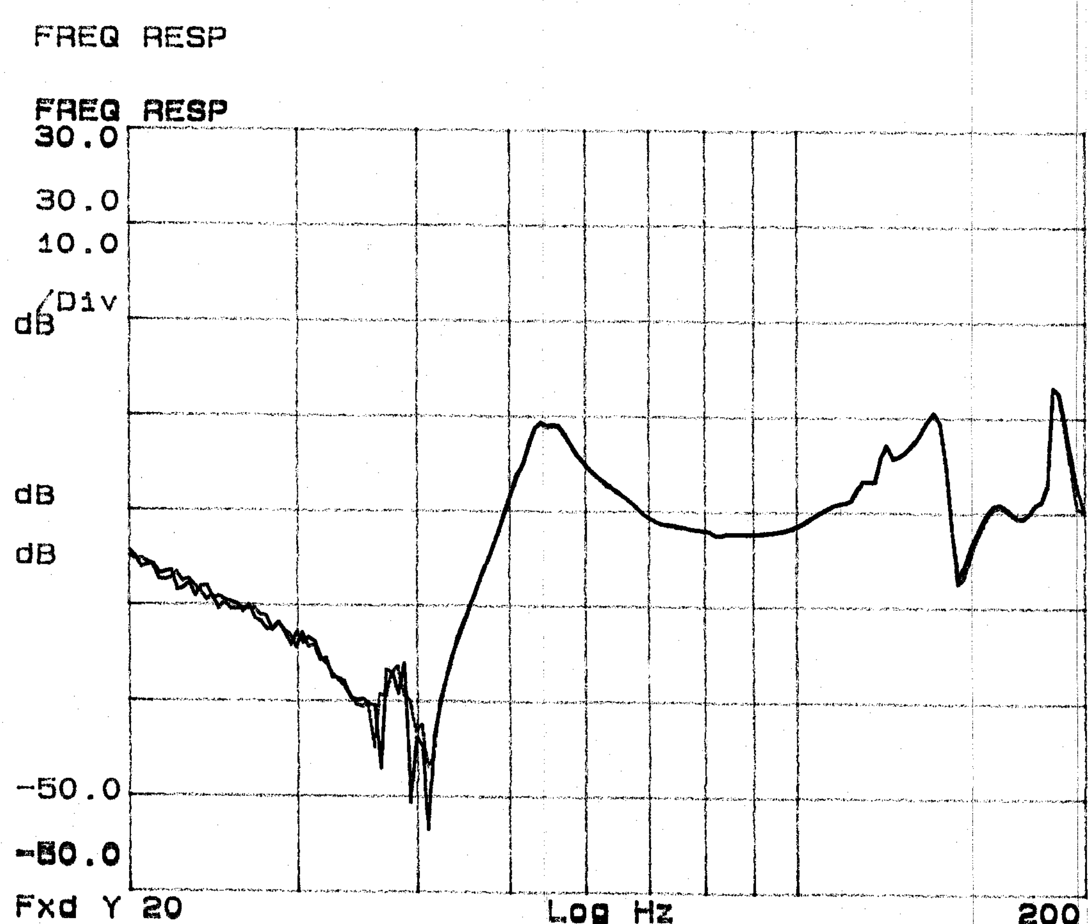
Oct 15, 1992
3:45 PM

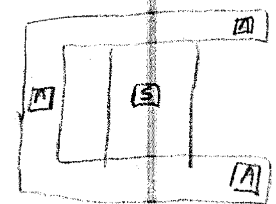




Oct. 14, 199

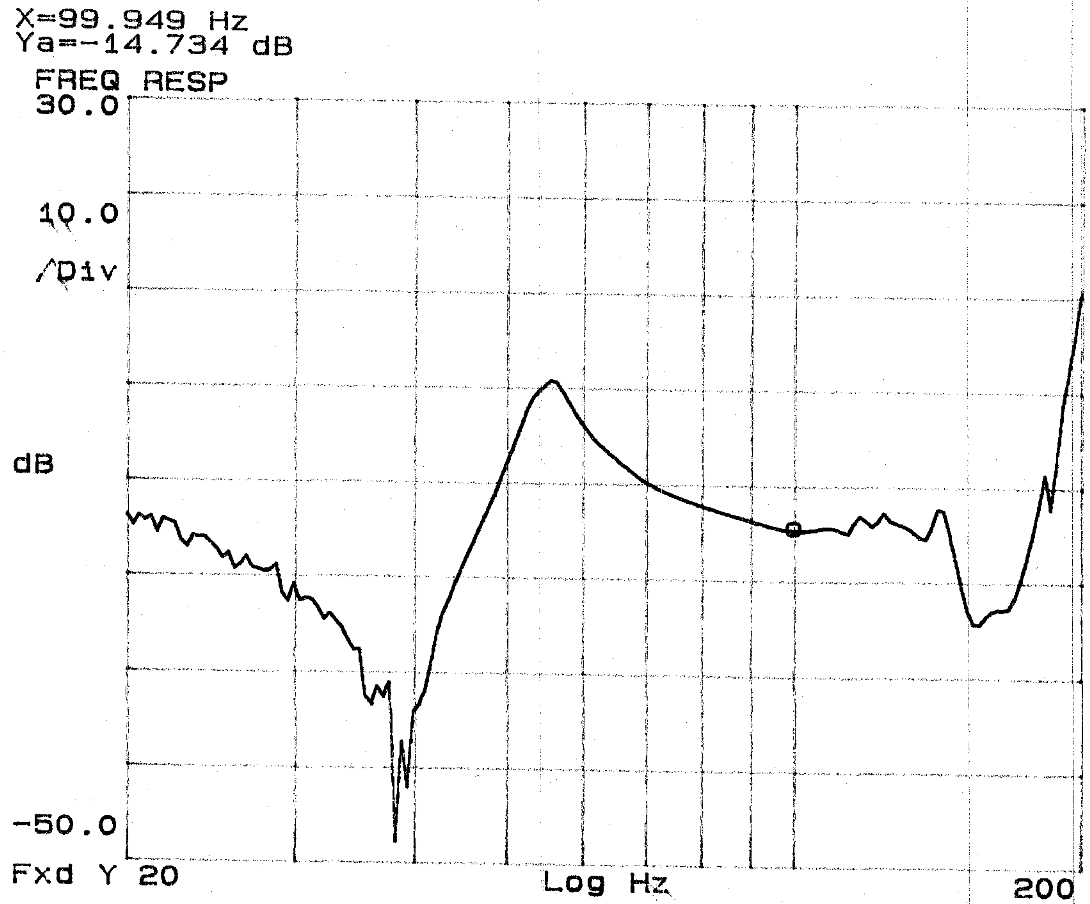
Vertical Transfer ftns from source voltage to 3 support points — All 3 were identical

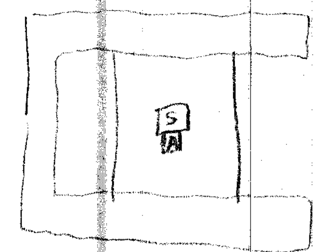


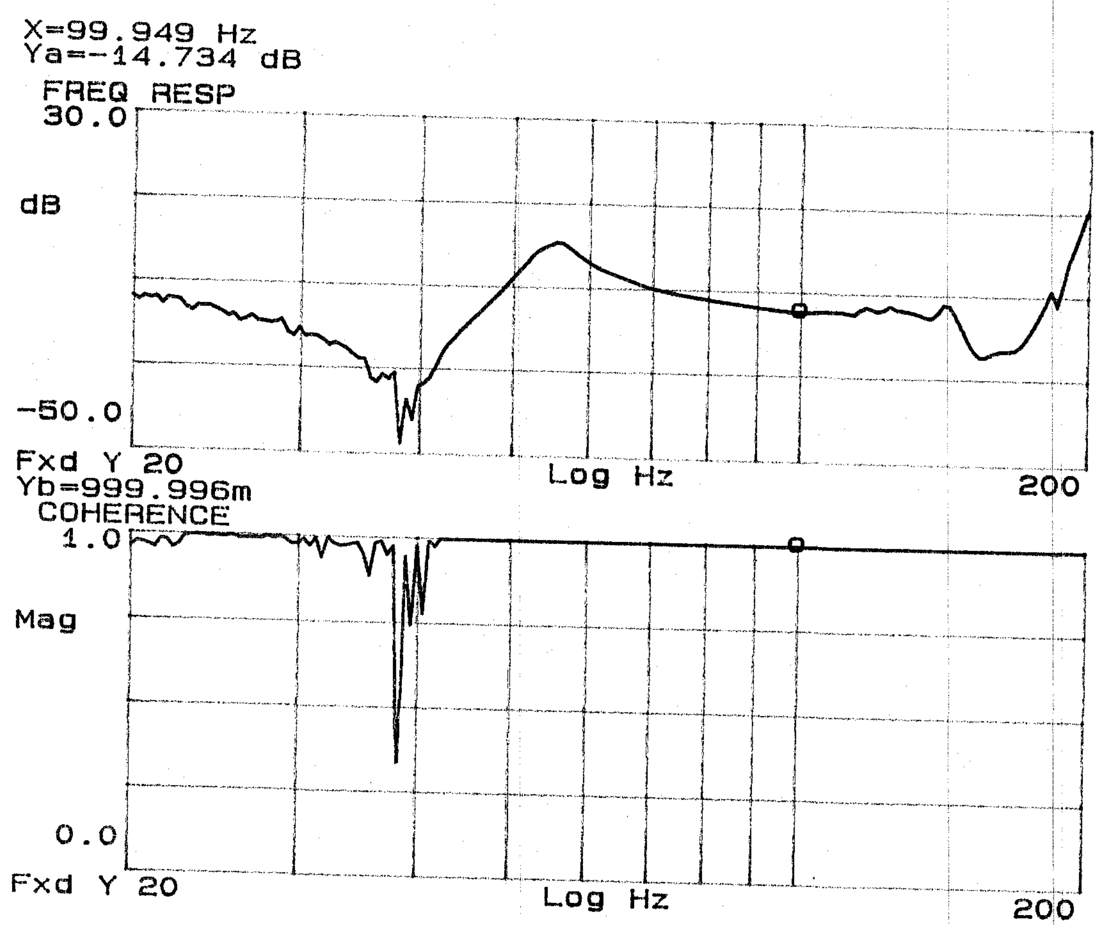


Oct. 19, 1992
1:55 PM

Vertical transfer fcn to
Shaker voltage to accelerometer
next to shaker

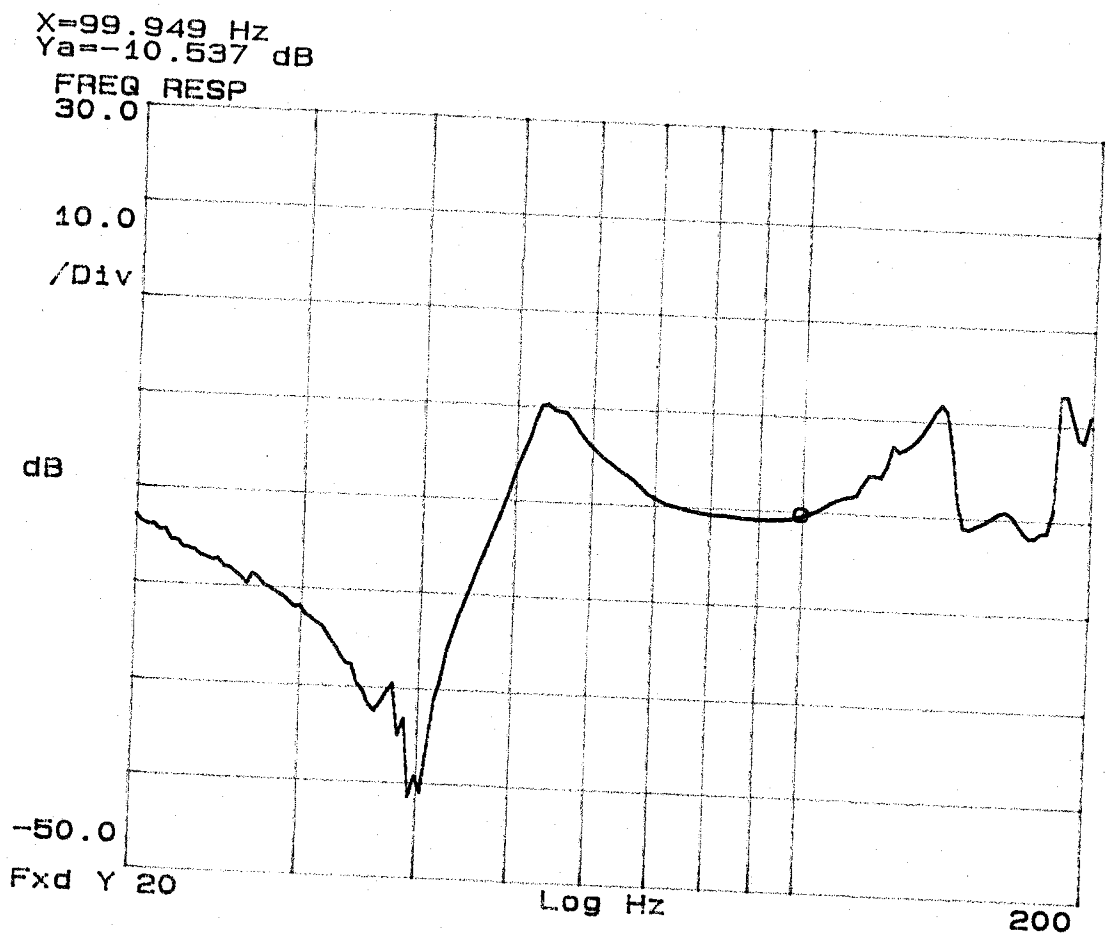


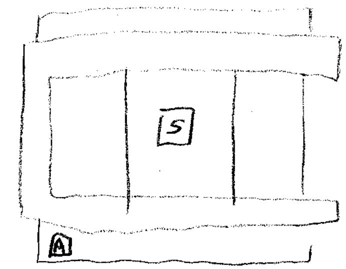


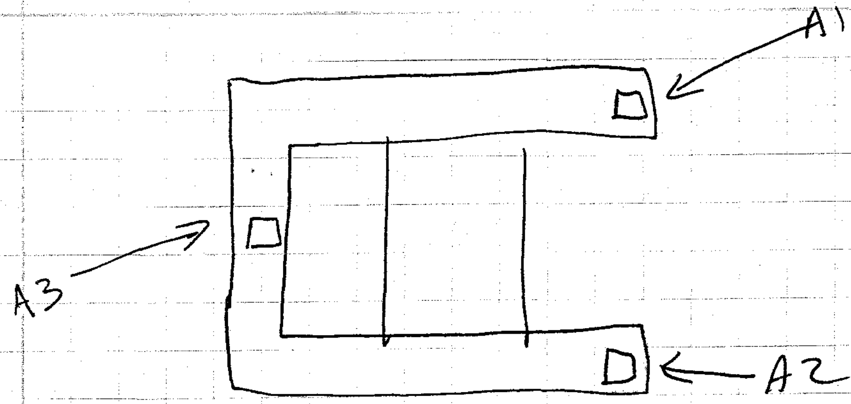

X=99.949 Hz
Ya=-14.734 dB
FREQ RESP
30.0
dB
-50.0
Fxd Y 20
Log Hz
200
Yb=999.996m
COHERENCE
1.0
Mag
0.0
Fxd Y 20
Log Hz
200

Oct, 19, 1992
2:05 PM

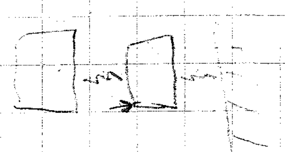
Vertical transfer Fctn
from source voltage
to accelerometer voltage







Did transfer functions from source shaker voltage to each of the three plates that the support structure are mounted on (in vertical position) - they were all identical over a 200 Hz span

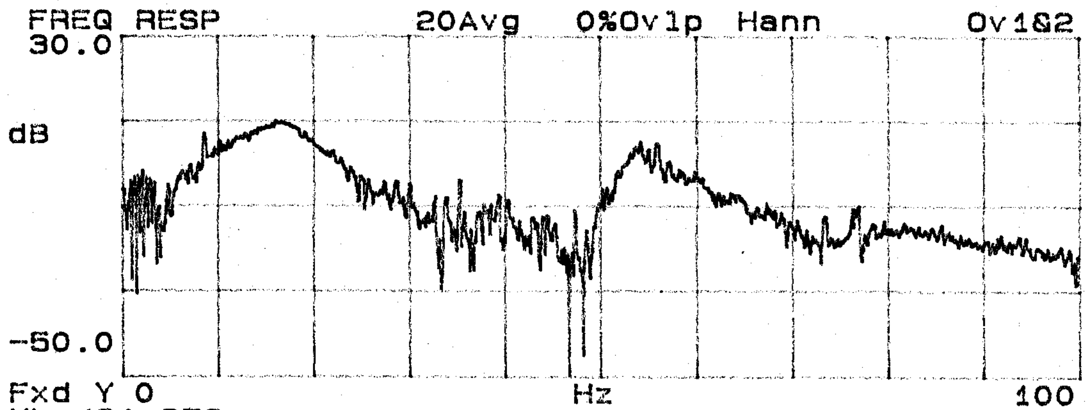


1:30 PM

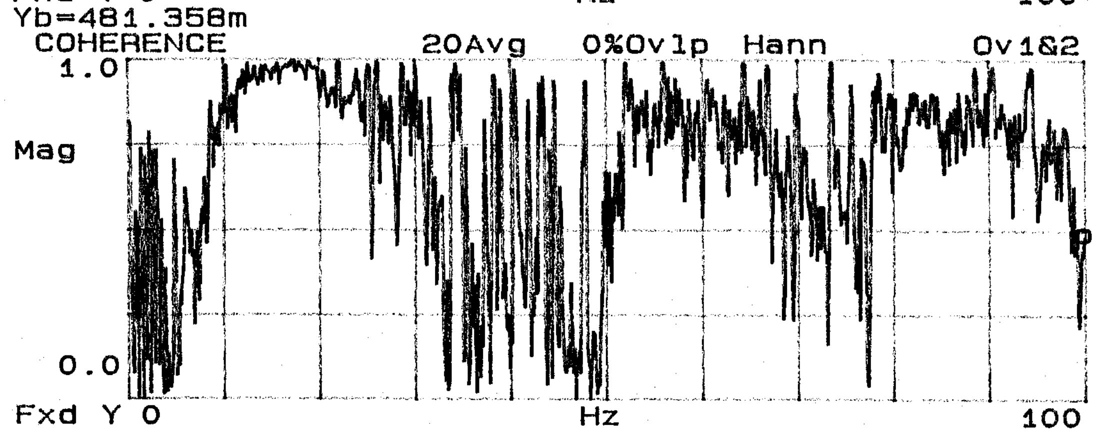
Transfer function in vertical direction from floor to optics table (ground noise excited)

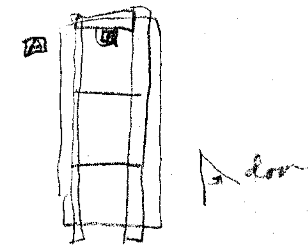
X=100 Hz

TF5



TF4



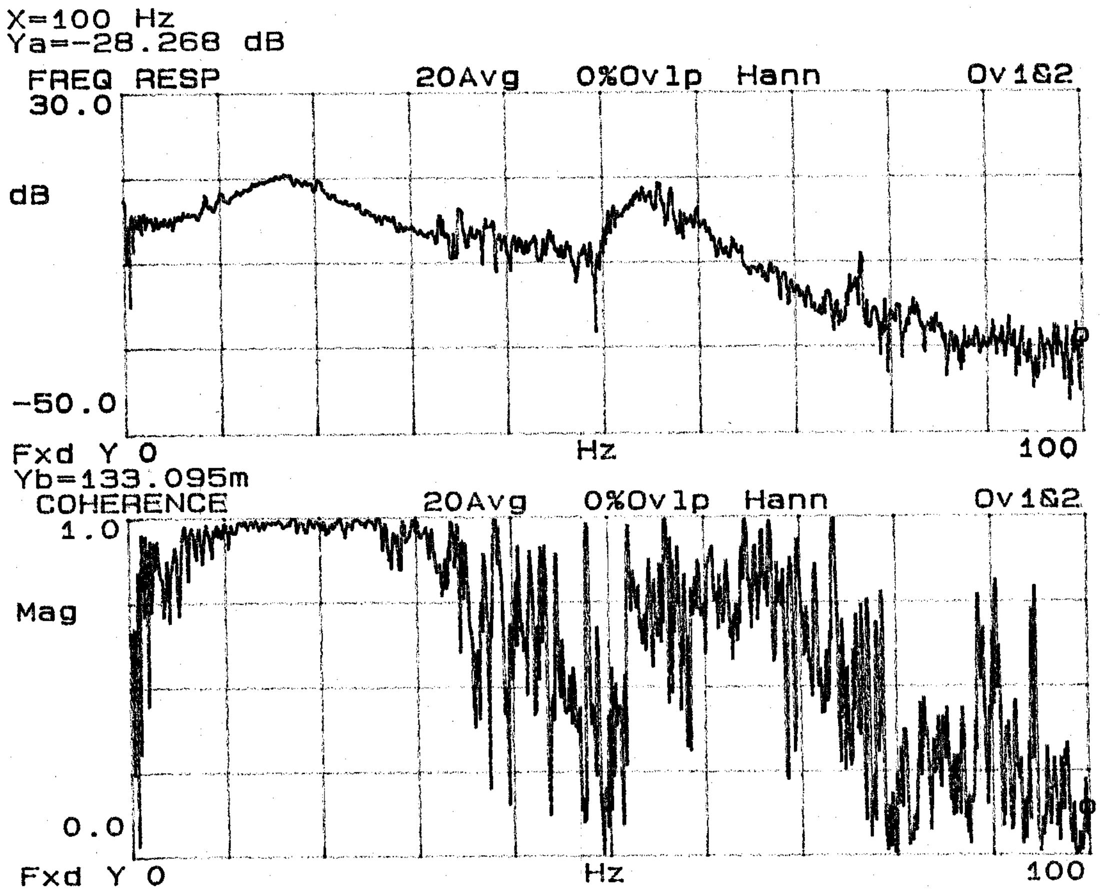


Accelerometer at base of optics table and at base of drift compensation under cross bar

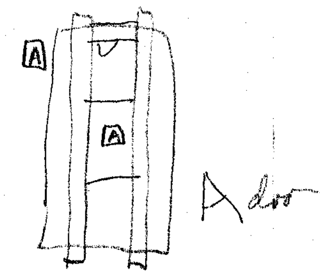
October 19, 1992
1:45 PM

Transfer function in vertical direction from floor to top of base plate

TF6



TF7

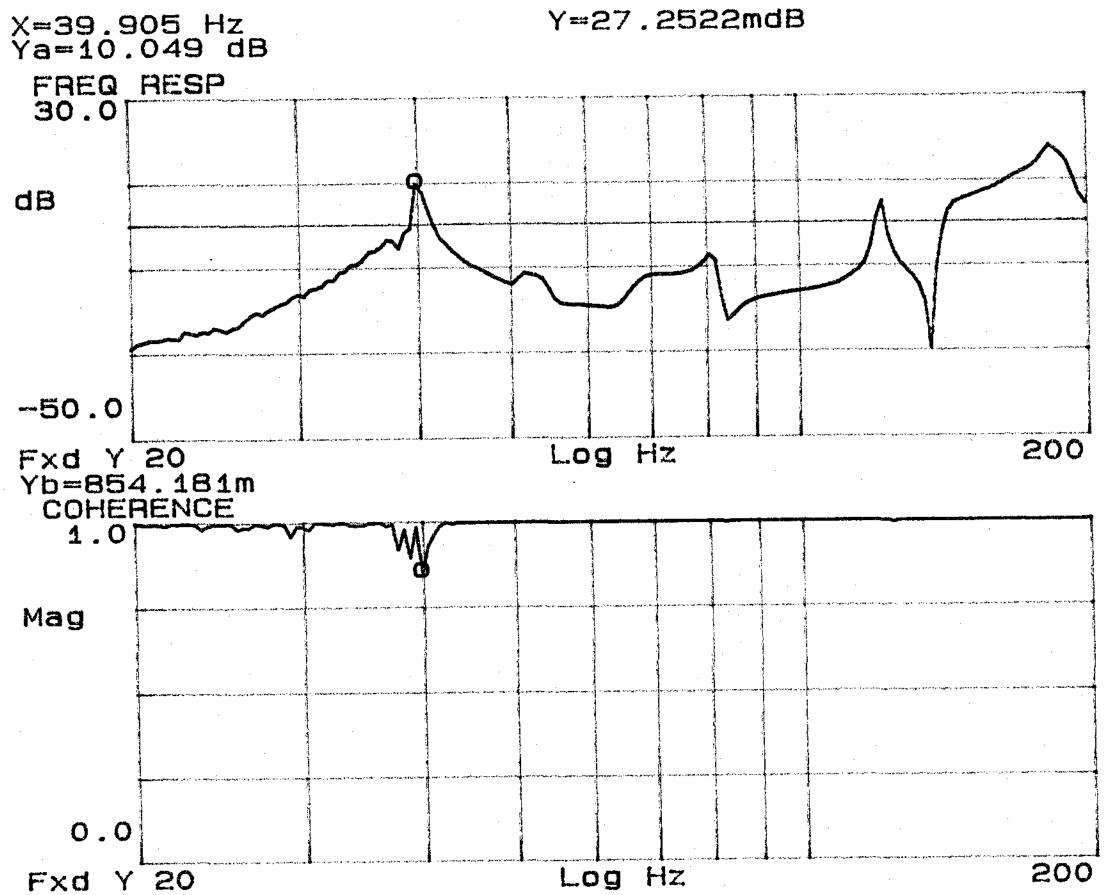


Accelerometer at base of optics table and in center of base base plate

49

10/14/92
4:30 Pm

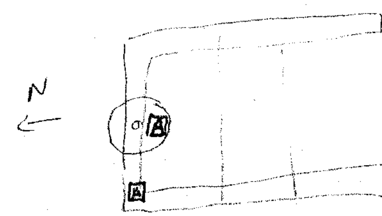
— Vertical to horiz. transfer fctr.



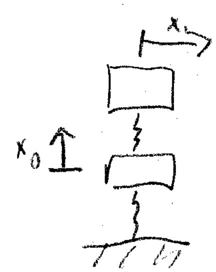
TF8

TF9

- Shaker is shaking vertically
- accelerometer on optics table at North diff/compensator
- accelerometer on N-W side of support structure



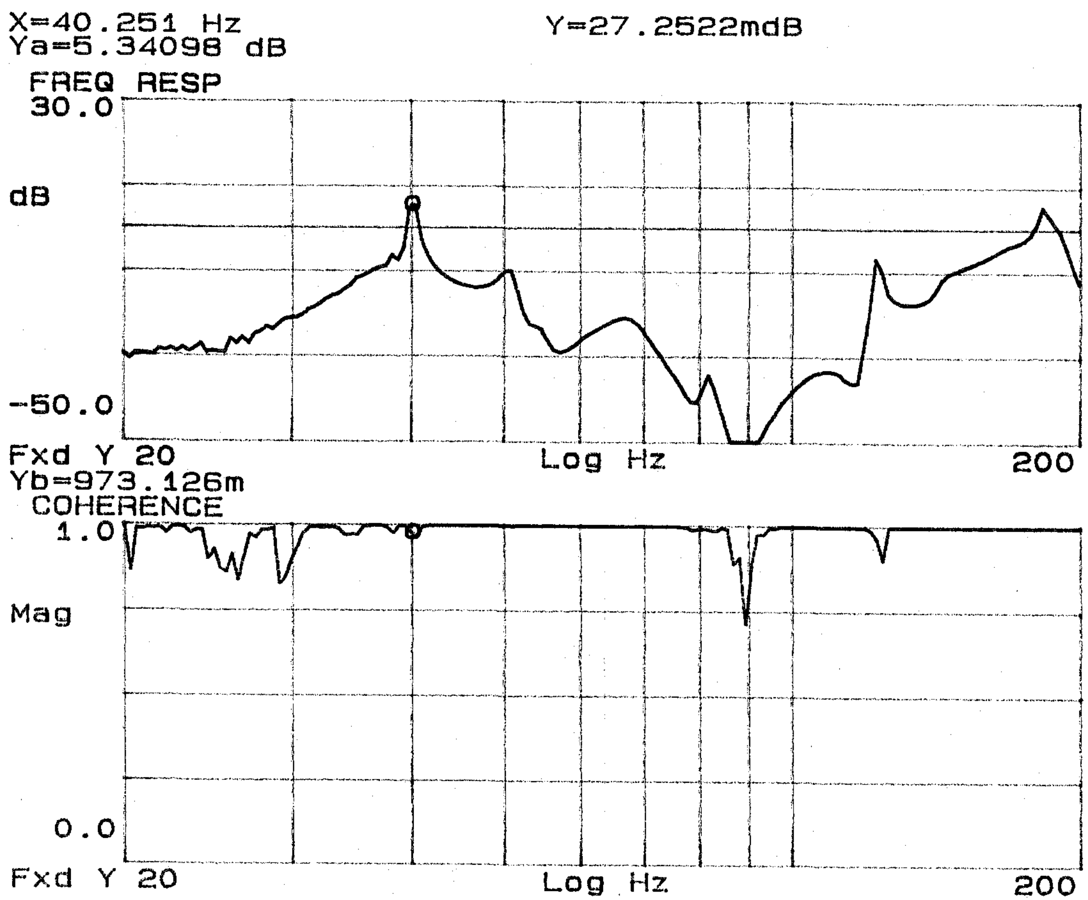
Ave = 2
Integ time = 500 msec
Source level = 100 mVrms
Gain setting = max



10/14/92
5:00 PM

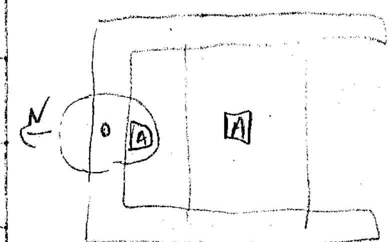
- Vertical to horiz transfer fcn.

TF10

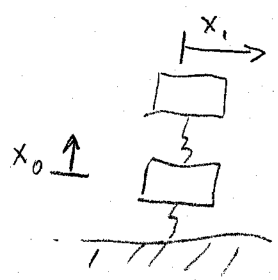


TF11

- shaker is shaking vertically
- accelerometer on optics table at North drift compensator
- accelerometer on center of support structure



Ave: 2
Integ time: 500 msec
source level: 100 mV rms
Gain setting: max

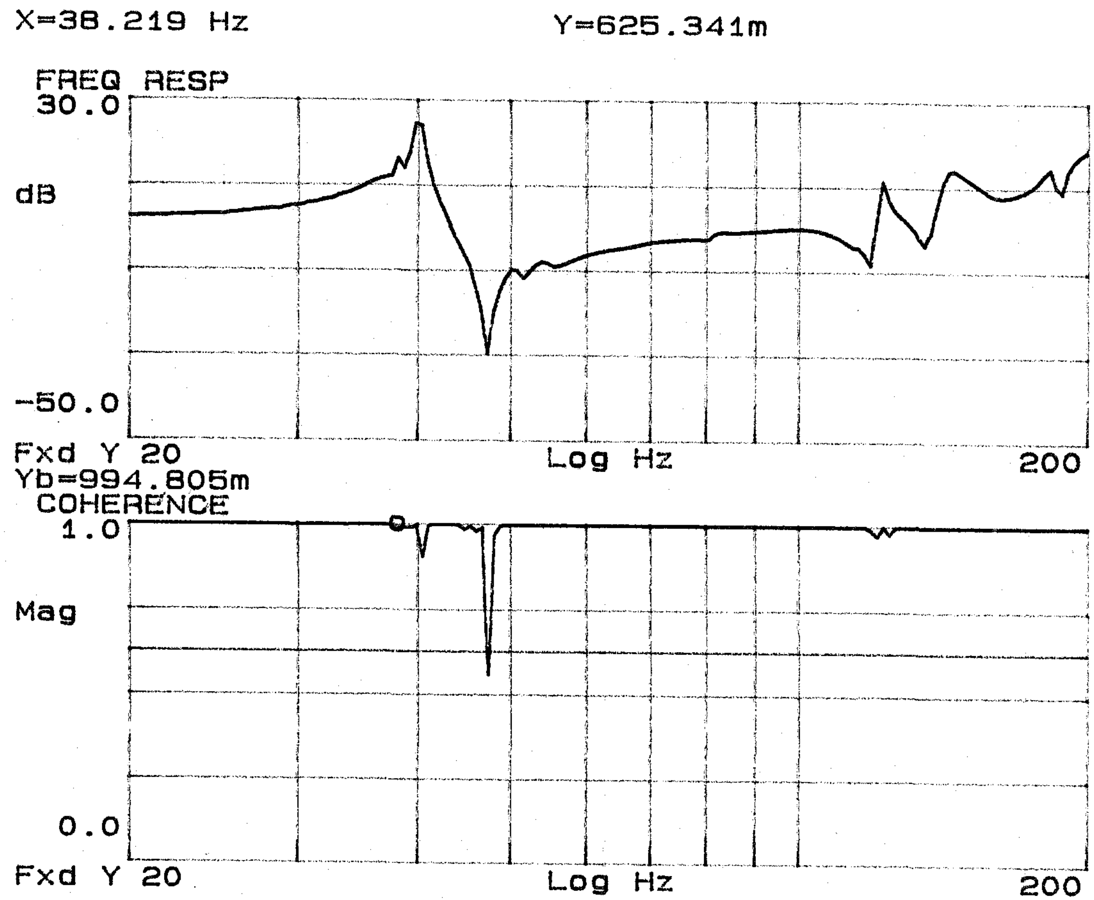


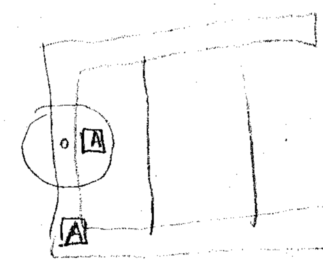
10/19/92
5:15 PM

- VtoV transfer fctn
- V shaker
- accel on NW corner of SS (Top)
- accel on North drift compensator on optical table (Bottom)

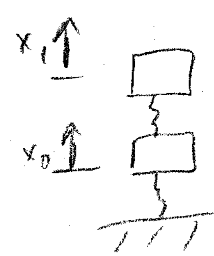
TF12

TF13





- Same as SST3.
- N to resonance has shifted

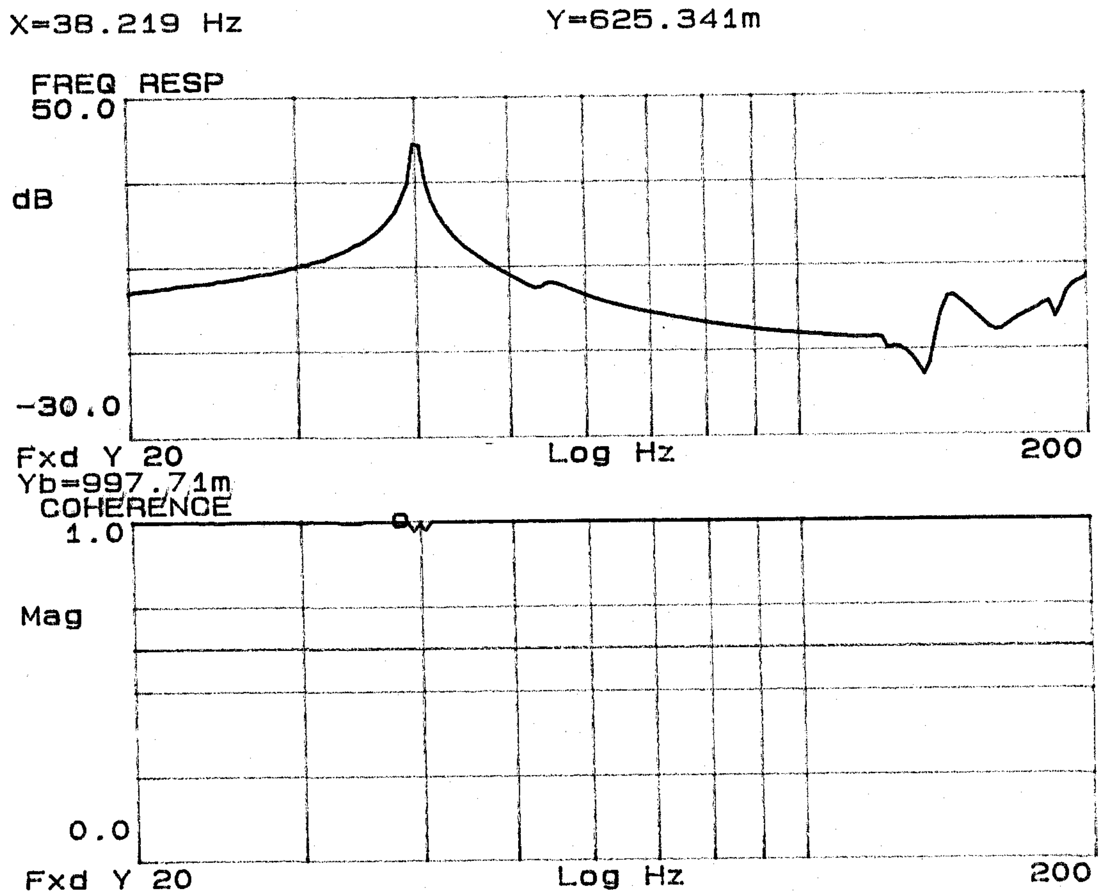


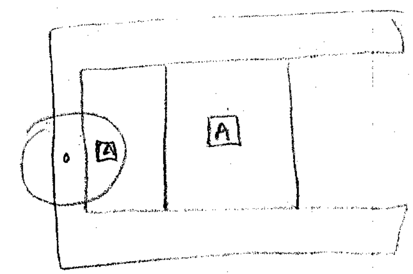
10/19/92
5:35 PM

- Y to V transfer f'cn with V shaking
- accel on center of SS (top)
- accel on North drift compensator on optics table (Bottom)

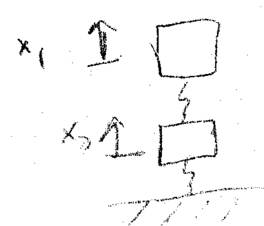
TF14

TF15





- Same as SS1 2
- Note nodes shifted



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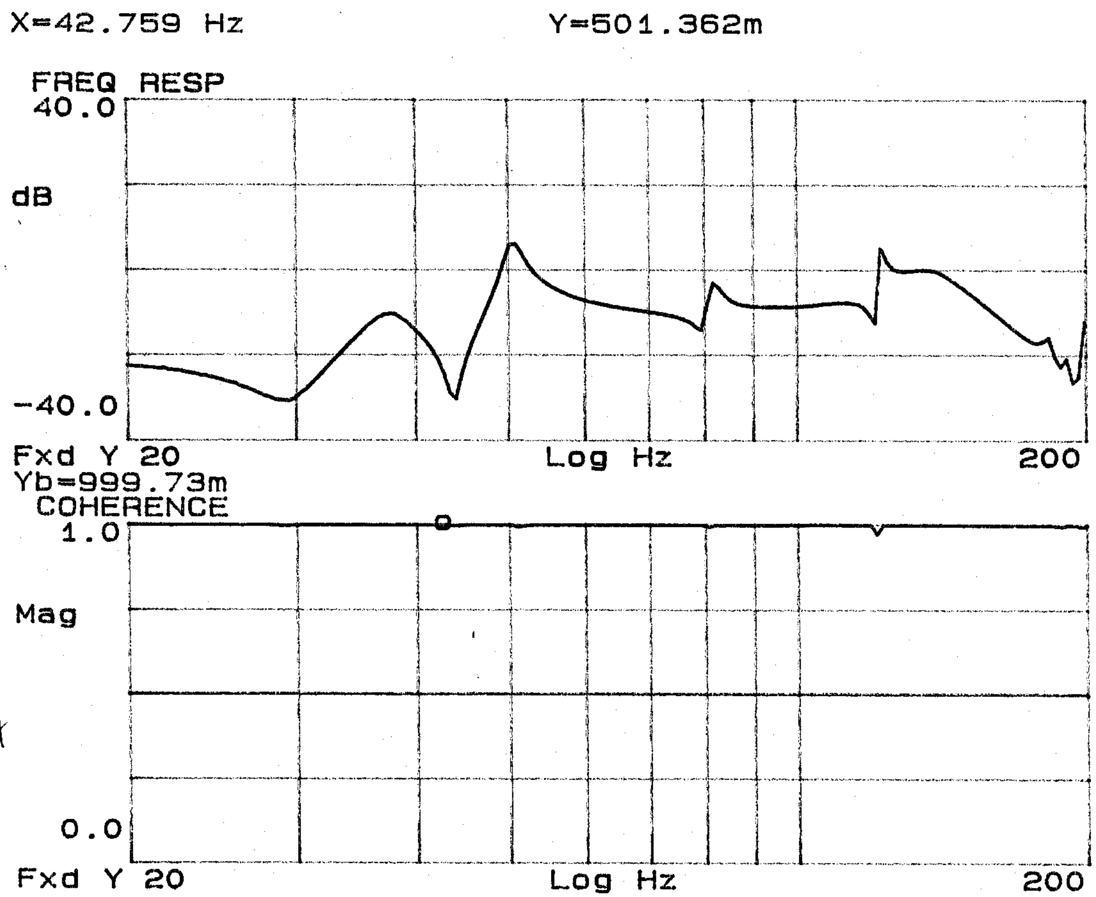
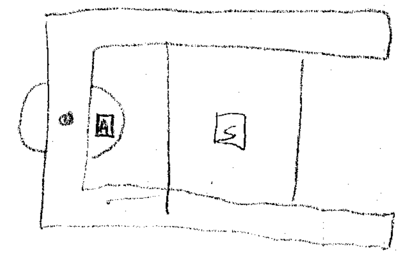
Oct. 20, 1992
9:00 AM

Transfer Fctr from Source voltage to accelerometer at base of North draft compensation

TF16

TF17



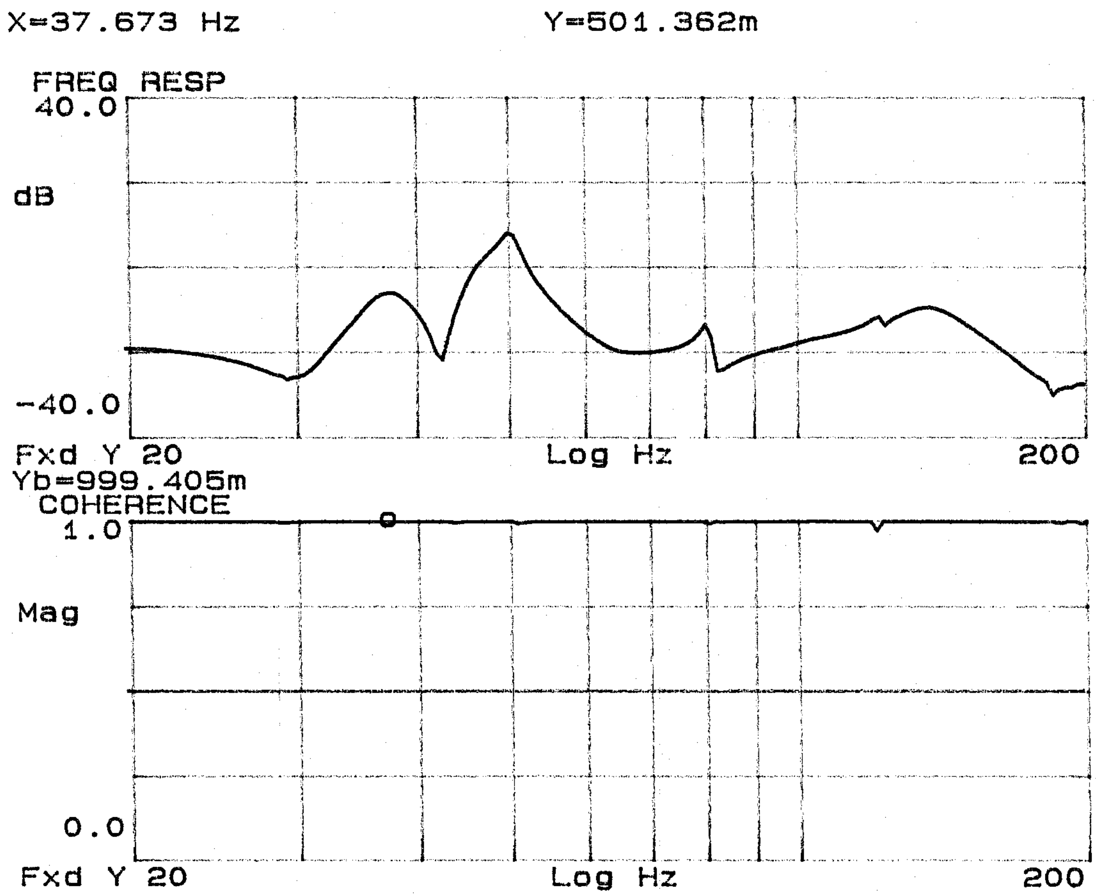


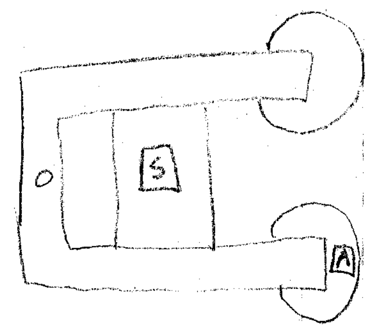
Source = 100mVrms

Oct. 20, 1992
9:50 PM

H-TF from source voltage to accelerometer at base of Southwest drift compensation

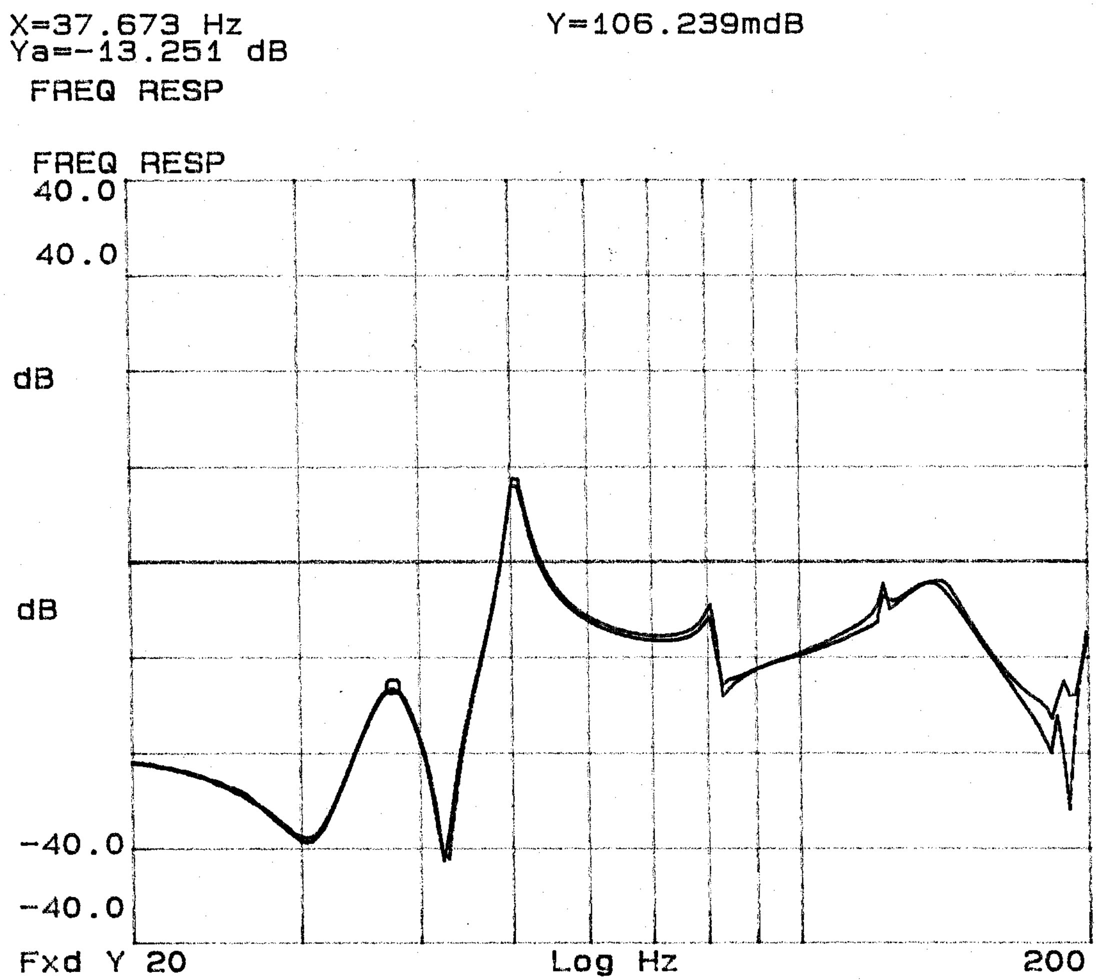
TF18





Source = 100 mVrms

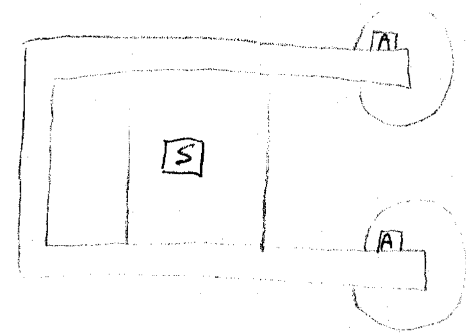
Oct 20, 1992
12:00 PM



- Transfer fctns from source voltage to horizontal accelerometer position
- Shaker in horizontal orientation
- Source = 100 mVrms gain = full

blue : TF20

black : TF21

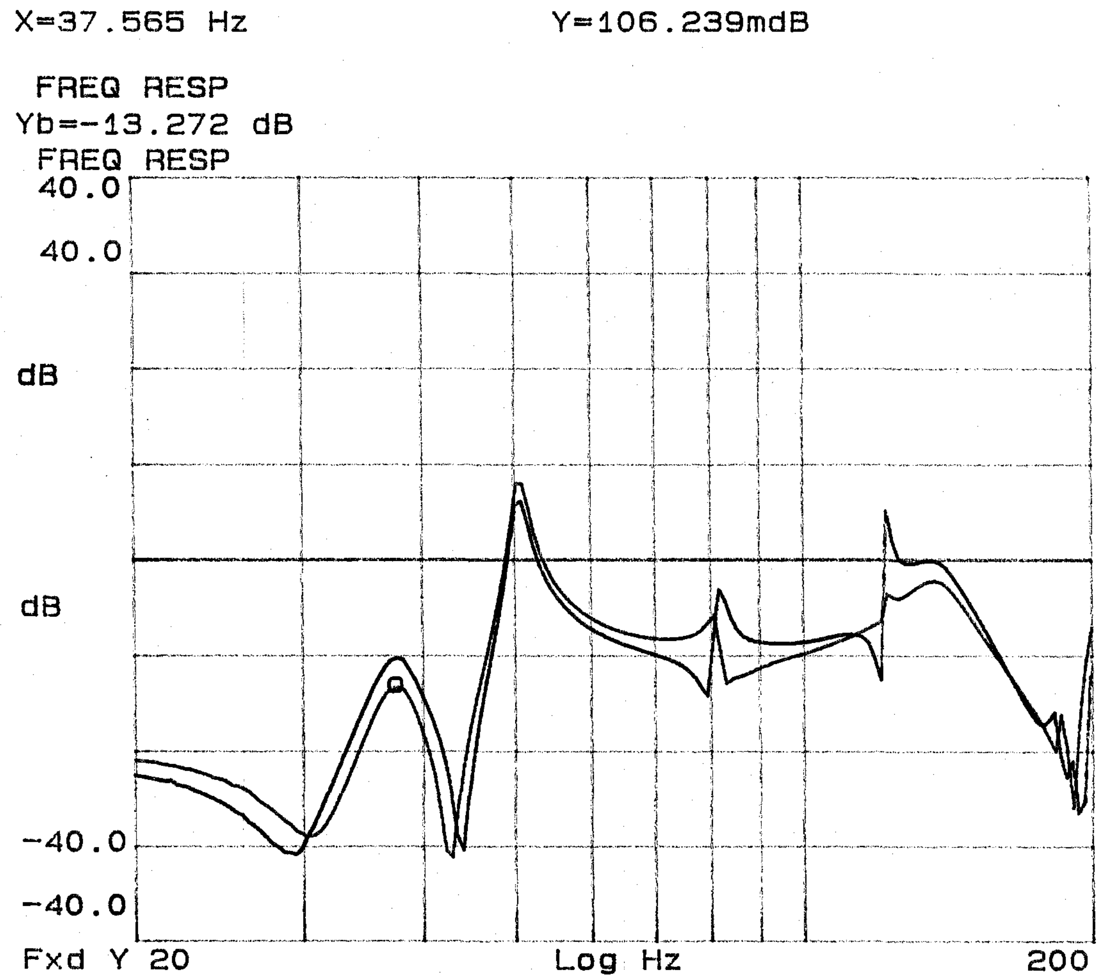


TF20 is from shaker to drift compensation on SE side (accel on drift compensation support plate)

TF 21 is from shaker to drift compensation on SW side (accel on drift compensation support plate)

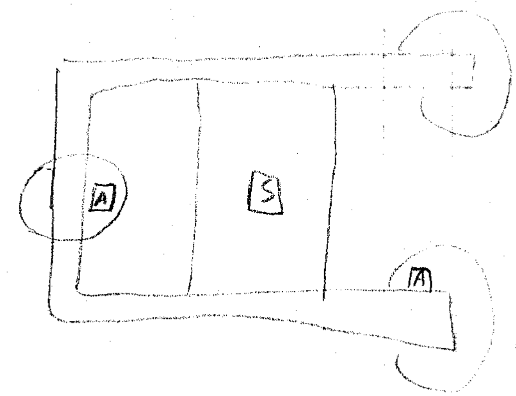
Shows that table is acting as a rigid body in the horizontal direction

[illegible]
1:00 PM



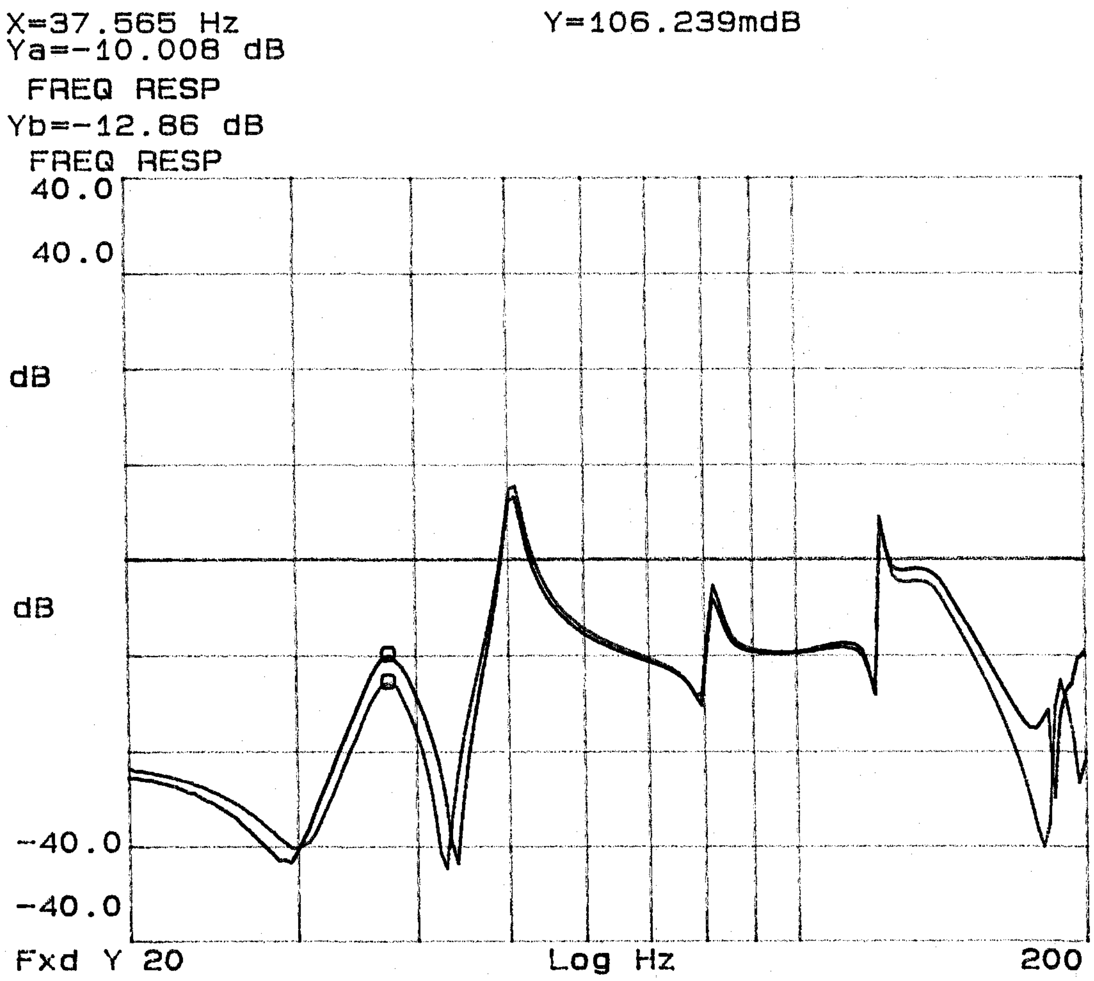
- TF from Source voltage to horiz accel.
- shaker in horiz position
- Source level 100mV rms gain = full

Blue: TF21
Black: TF16



TF16 is from shaker to drift compensation on North side
TF21 is from shaker to drift compensation on SW side

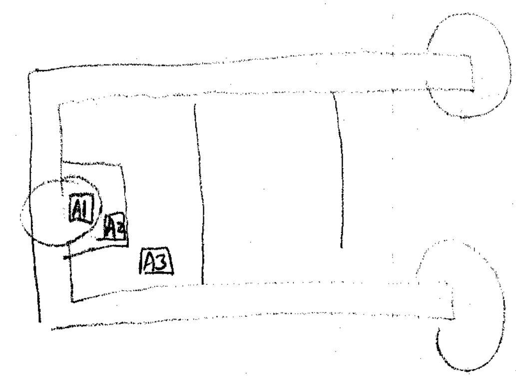
3:00 PM



Blue: TF16

Black: TF22

- TF from source voltage to horizontal accel.
- shaker in horiz position
- source level: 100mVrms gain = full



TF22 is transfer fctn from source voltage to A2 (same as source to A3)
TF16 is transfer fctn from source voltage to A1

Tightened bolts on N dwf compensator Support Plate

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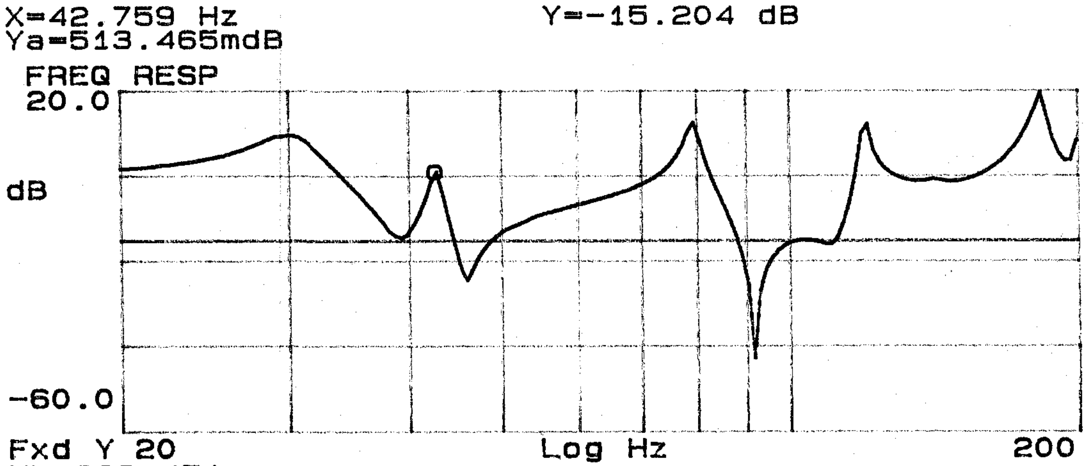
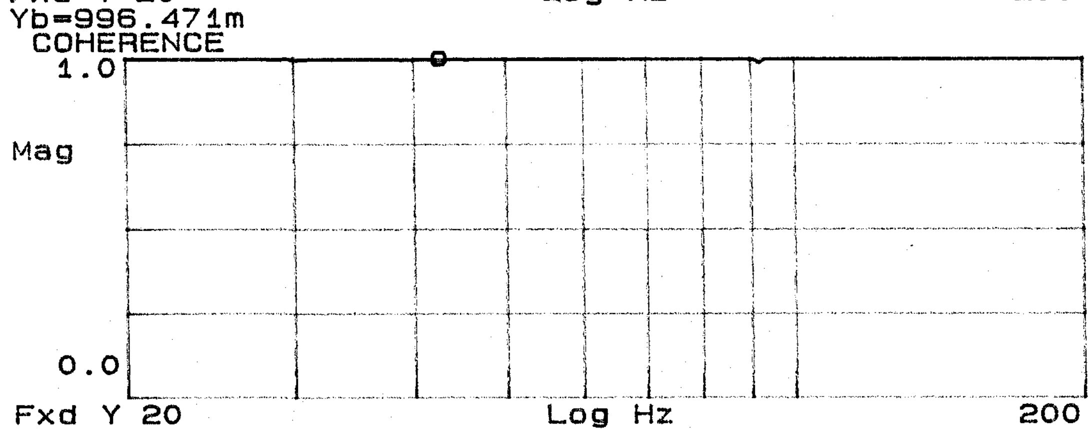
5:00 PM

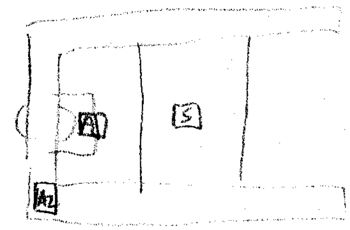
- TF from H to H weld H beam

TF23

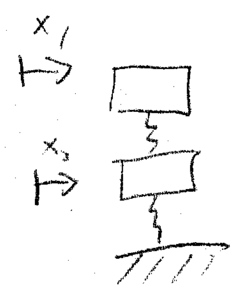


TF24





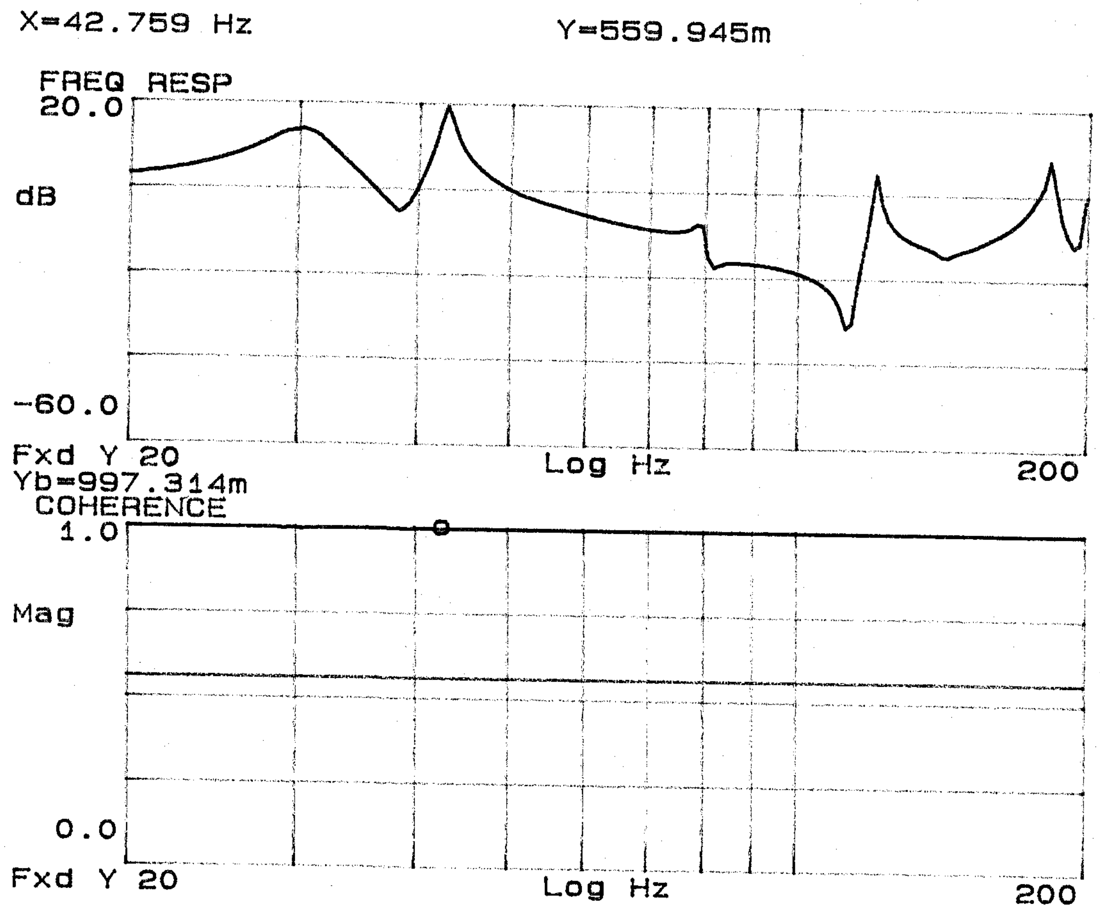
Bottom accel = A1
Top Accel = A2

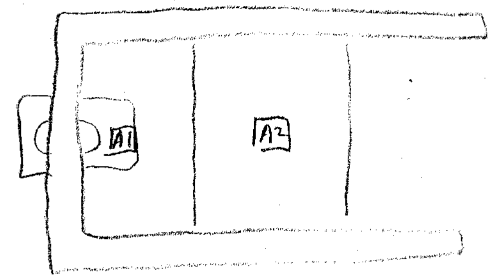


TF from H-to H with H drive

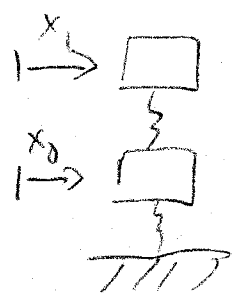
TF25

TF26





Bottom accel = A1
Top accel = A2



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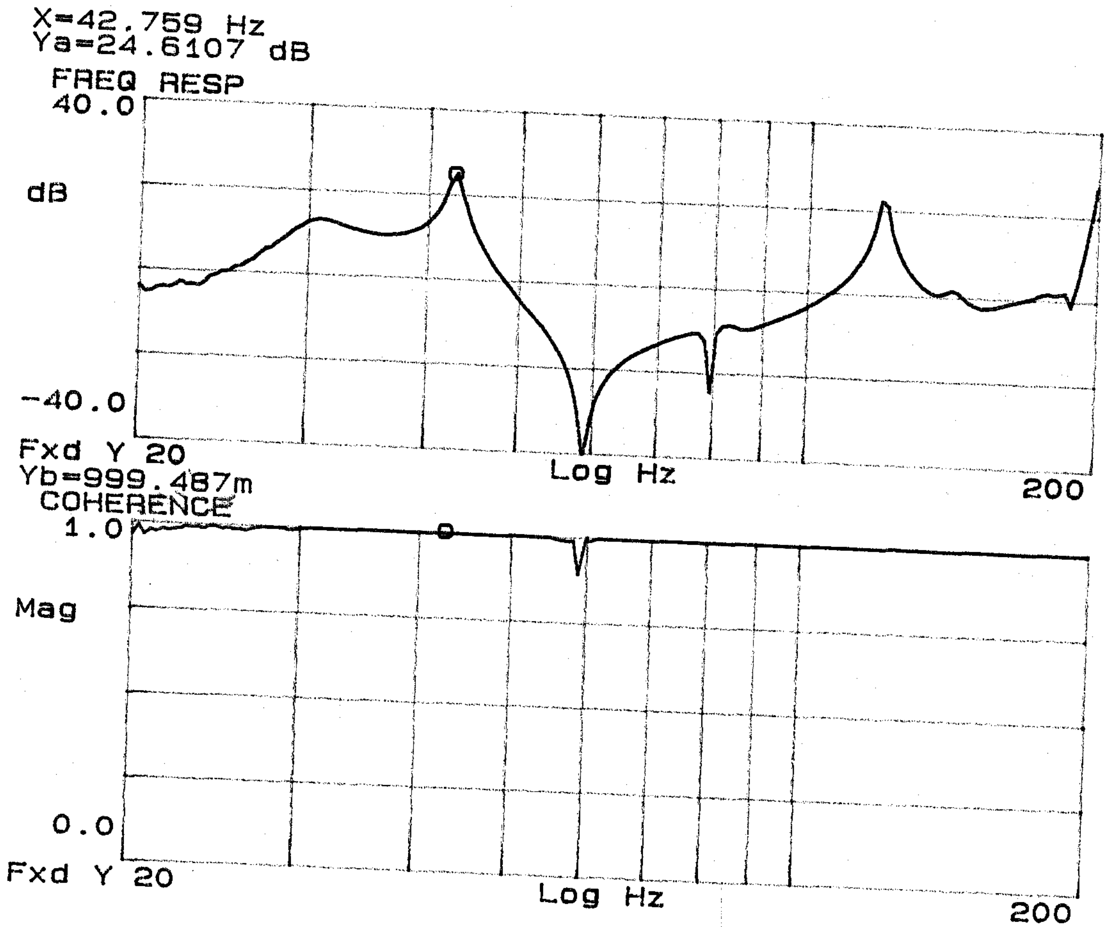
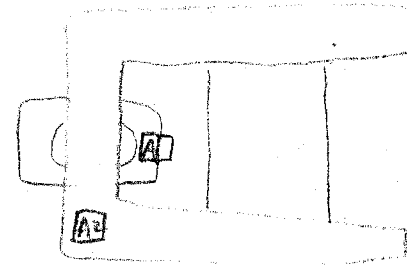
- Transfer fctn from longitudinal to vertical

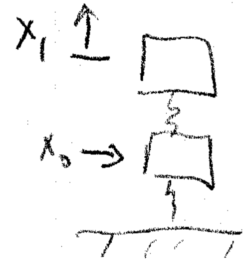
TF27

F28

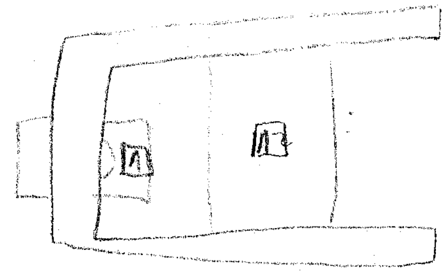




Source level = 100 mV rms
gain (amp) = full
Bottom accel = A1
Top accel = A2

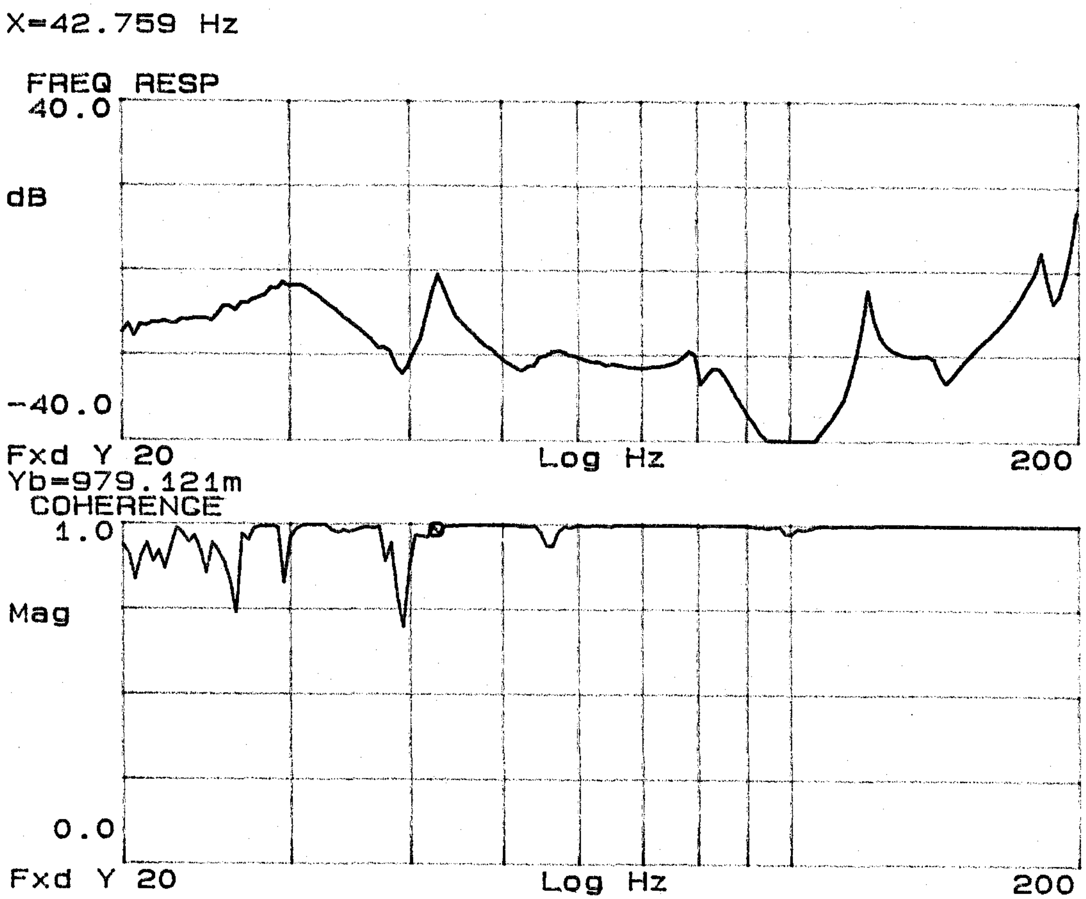


- Transfer Fcn from horiz to vertical

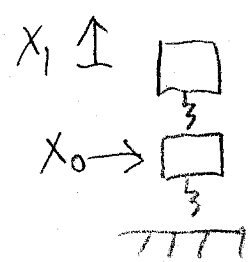


TF29

TF30



Source level = 100mV rms
gain (amp) = full
Bottom accel = A1
Top accel = A2



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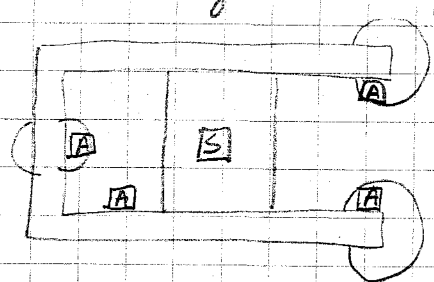
Conclusions From Test:

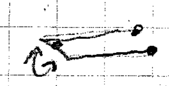
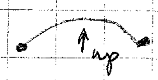
1) There are a number of floor resonances in both the V + H directions

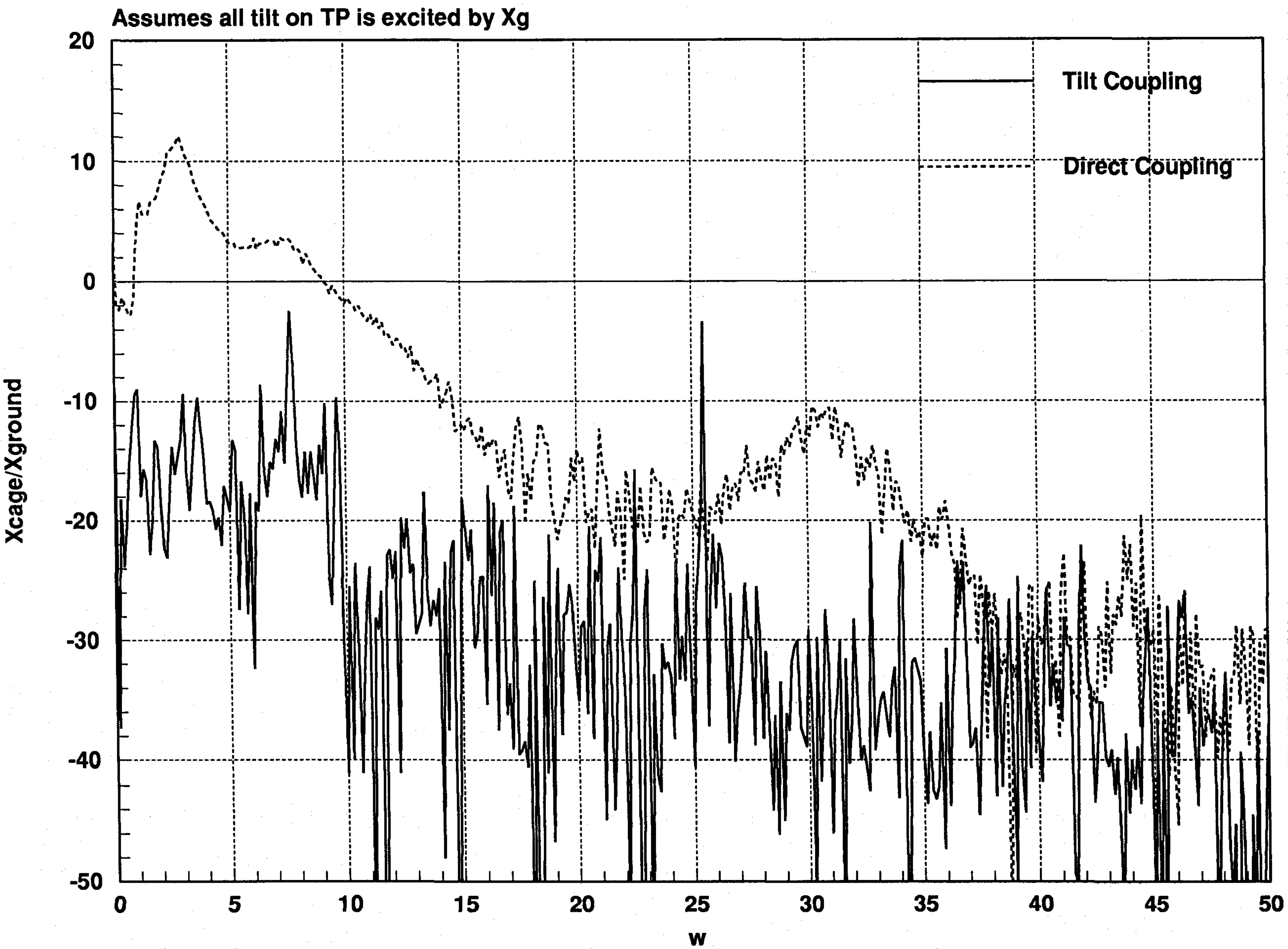
2) The SS and the optics table interact dynamically below 100 Hz but the table doesn't bend at these frequencies.
- The transfer functions from S to H are identical from shaker source voltage to each of the support points
- The transfer functions from S to V are identical from shaker source voltage to each of support points



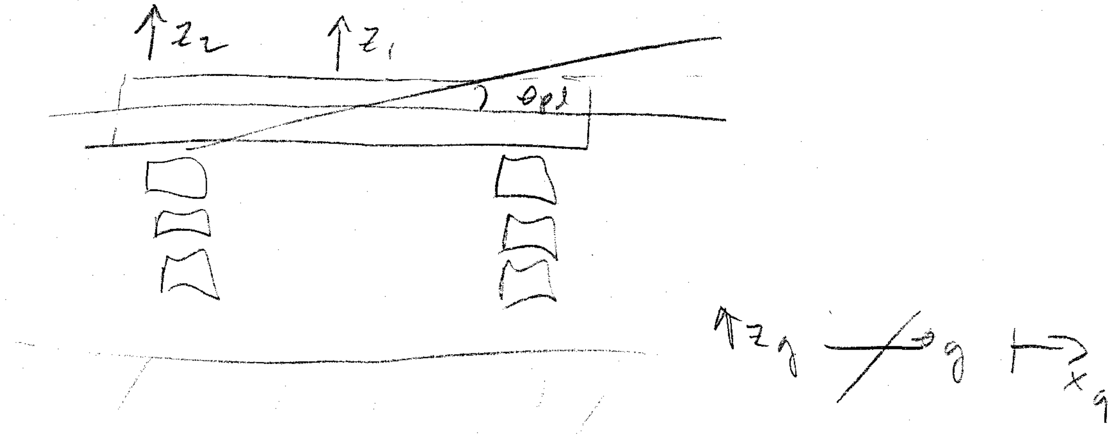
The conclusion from this is that we should be able to get an accurate picture of how the ground shakes the shake by only looking at the accelerometer at 1 site on the table

3) Internal resonances

	Expected	Measured (I think these are the correct resonances?)
	33 Hz	30 Hz
2nd 	53 Hz	40 Hz
3rd 	72 Hz	42.7 Hz



Upper Bound on H Transfer Functions Assuming Direct and Tilt Coupling



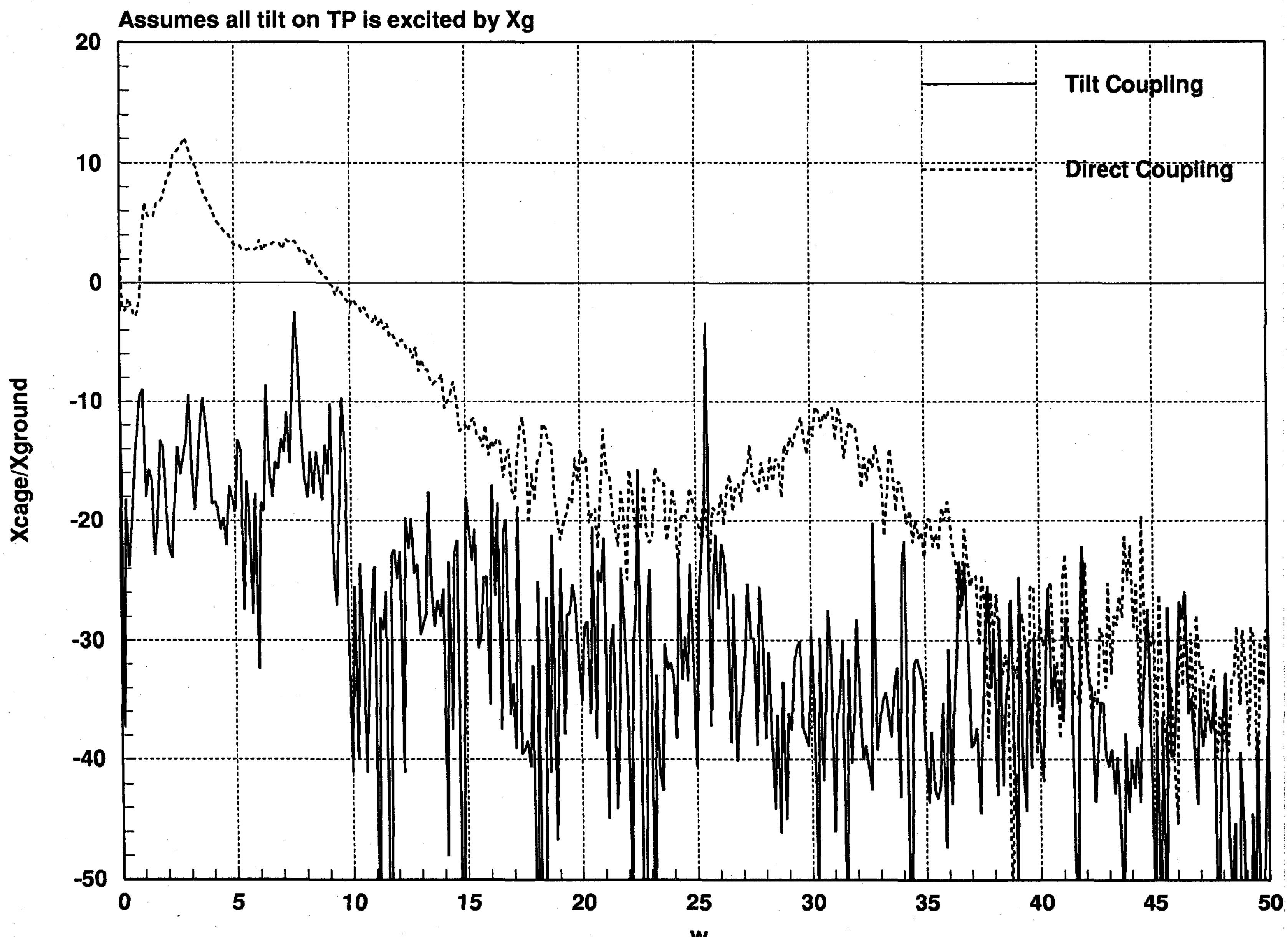
(1) $|z_2 - z_1| < |\frac{1}{10} z_1|$ ← from data

(2) $|\theta_{pl}| \approx \frac{(z_2 - z_1)}{R_{plate}} < \frac{|\frac{1}{10} z_1|}{R_{plate}}$ from 1

(3) $\left|\frac{\theta_{pl}}{ground}\right| < \left|\frac{\frac{\frac{1}{10} z_1}{R_{plate}}}{ground}\right| \sim \frac{1}{10} \frac{1}{R_{plate}} \left|\frac{z_1}{z_{ground}}\right|$

(3) $z_1 = \frac{z_1}{x_g} x_g + \frac{z_1}{\theta_g} \theta_g + \frac{z_1}{z_g} z_g \approx \frac{z_1}{z_g} z_g$

$\Rightarrow$ $|\theta_{pl}| < \left|\frac{\frac{1}{10} \frac{z_1}{z_g} z_g}{R_{pl}}\right|$

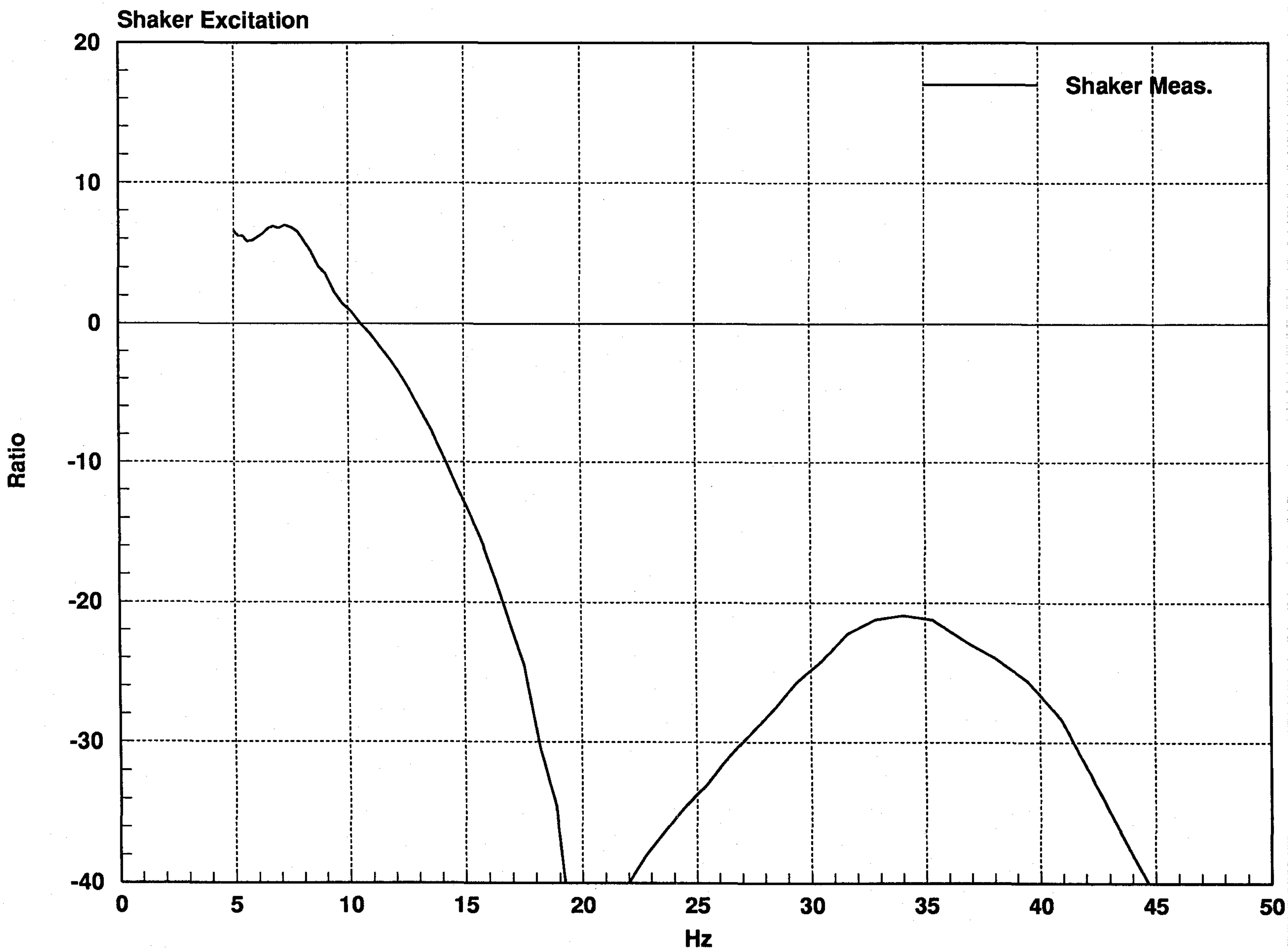


Upper Bound on H Transfer Functions Assuming Direct and Tilt Coupling

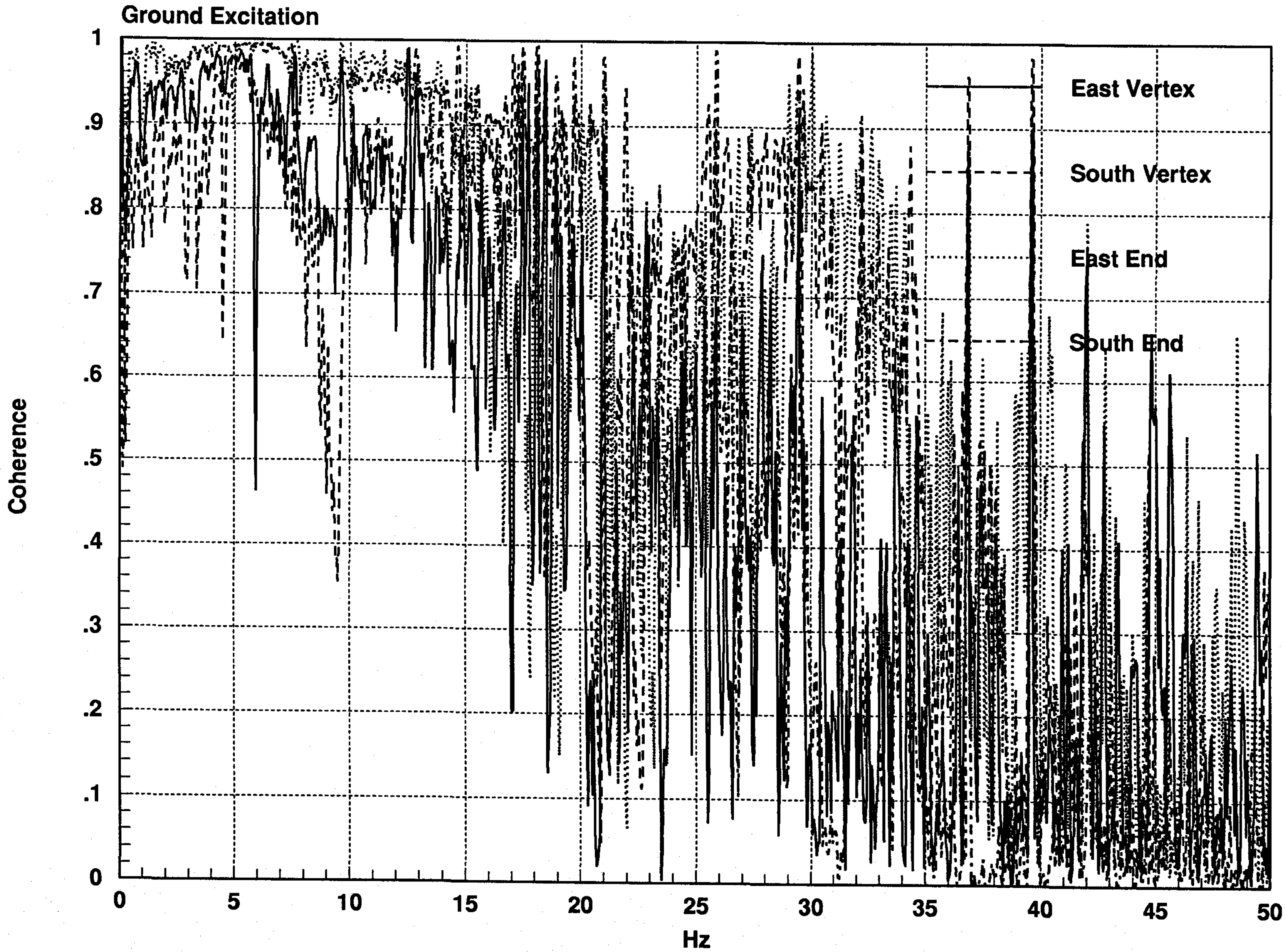
$$\frac{\theta}{\text{ground excitation}} = \left(\frac{z}{\text{ground}}\right)\frac{1}{10}\frac{1}{R_{\text{plate}}}$$

$$\frac{X_{\text{due to tilt}}}{\text{ground excitation}} = \frac{\theta\, R_{\text{cage}}}{\text{ground excitation}}$$

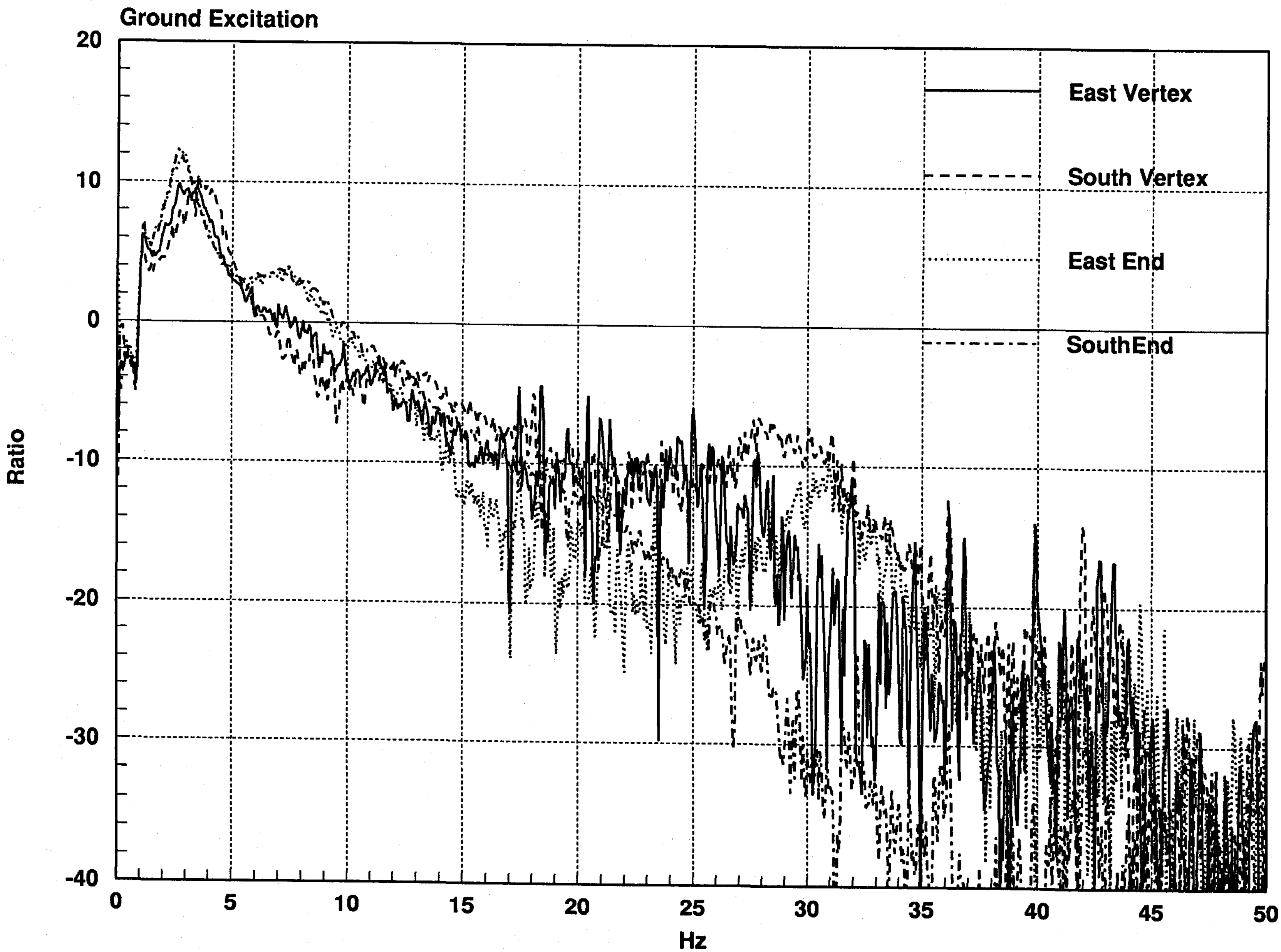
$$\frac{X_{\text{due to tilt}}}{\text{ground excitation}} = \left(\frac{z}{\text{ground}}\right)\frac{1}{10}\frac{R_{\text{cage}}}{R_{\text{plate}}}$$



H to H TFs of Stack on Support Structure (vst)



Coh of Vertex & End (seis_sv1 seis_sv9 tiltse29 eept10)



H to H TFs of Vertex & End Stacks (seis_sv seis_sv8 tiltse28 eetp9)

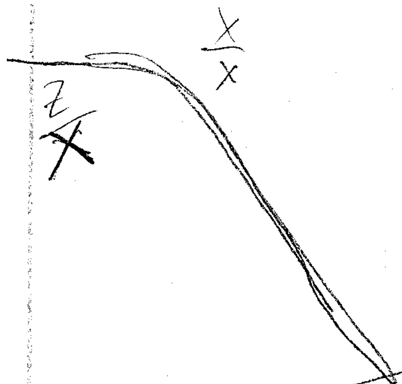
Analysis of (1)

If a-b with R=0 & R=35" are equal
⟹ at noise level of tilt on top plate
since a-b should scale with R

Analysis of (2)

same as (1)

Analysis of (3)



want a handle on
$\frac{\theta_{TP}}{X_g} + \frac{\theta_{TP}}{\theta_g}$

Want to figure out if
$\frac{\theta_{TP}}{X_g} X_g$ or $\frac{\theta_{TP}}{\theta_0} \theta_g$ dominates

check in Joe's paper $\frac{\theta}{\theta}$ & $\frac{\theta}{X}$

$\left(\frac{Z}{X}\right)_{TPH} = \left(\frac{Z}{X}\right)_{\text{common mode}} \pm \left(\frac{R\theta}{X}\right) Y \approx \frac{Z}{X}$ common mode

has a measurement? ⟺ see if this dominates

Believe $R\theta$ small compared

then $\frac{\theta}{X}$ is small compared to

$c = \lambda \nu$

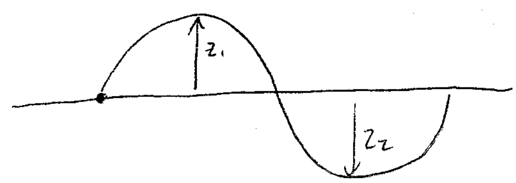
<u>air</u> $\nu = 1\ hz \Rightarrow \lambda = 331\ m$

$c = 331\ m/sec$ $\nu = 50\ Hz \Rightarrow \lambda = 6.6\ m = 21.6\ ft$

$\nu = 30\ Hz \Rightarrow \lambda = 11\ m = 36\ ft$

<u>concrete</u> $\nu = 1\ hz \Rightarrow \lambda = 3100\ m$ =

$c = 3100\ m/sec$ $\nu = 50\ hz \Rightarrow \lambda = 62\ m$.



$\frac{1}{2}\lambda$ get $z_1 - z_2 = 2z_1$

$\frac{1}{4}\lambda$ get $z_1 - z_2 \sim z_1$

$\frac{1}{8}\lambda$ get $z_1 - z_2 \sim \frac{z_1}{2}$

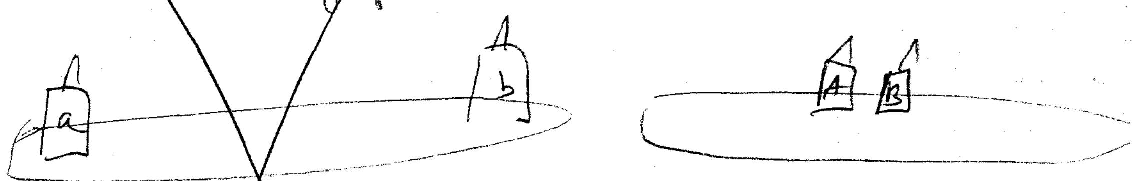
concrete $\frac{1}{4}\lambda \geq 15\ m$ at 50 Hz

air $\frac{1}{4}\lambda \sim 5.4\ ft$

$\frac{1}{8}\lambda \sim 2.7\ ft = 32.4''$

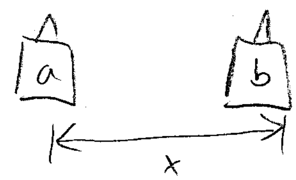
Tests for T.Ps

* 1) Measure tilt on top of stack



a) want to get a-b & a simultaneously
b) also want $\frac{a}{b}$ & coherence

2) Want to get better idea of tilt on floor

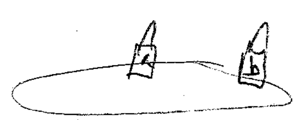


x = 5"
= 10"
= 20"
= 40"

a) a-b & a simultaneously
b) $\frac{a}{b}$ & coherence

* 3) Want to get coherence between vert & horiz ground motion

a) $\frac{a}{b}$ & coherence

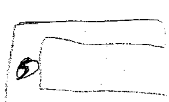


b) If no coherence do $\frac{X_{TP}}{Z_g}$ & $\frac{Z_{TP}}{X_g}$

~~If there is coherence still do $\frac{Z_{TP}}{X_g}$ & get upper bound~~

If there is coherence do $\frac{Z_{TP}}{X_g}$

4) Do $\frac{X_{TP}}{X_g}$ over night & see what data looks like

* 5)  try to do tilt transfer fctn (V1) (V2)

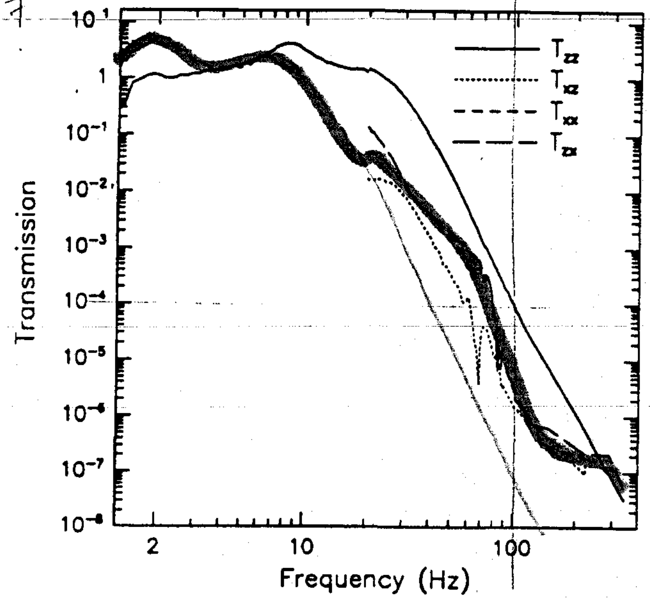
would for the ground noise drive expected in the intended application.

2. Low-frequency ground-noise-driven measurements:

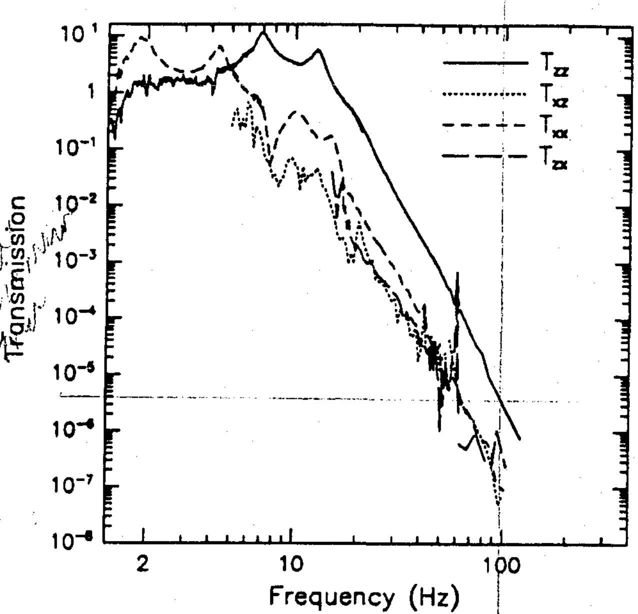
At low frequencies, the stack's response is strongly influenced by the exact shapes and frequencies of the rigid-body modes, which range in frequency from approximately 1.5 to 25 Hz. The configuration we wished to characterize, and the one we modeled on the computer, was with the base fixed to a very large reaction mass. When the stack's base table is placed on springs, as was done for the high-frequency measurements, these low-frequency modes change frequency and shape because the table is a very different reaction mass than the floor-mounted posts. This doesn't greatly affect the high frequency measurements, but would distort any low frequency data taken with the base ungrounded. At frequencies below about 20 Hz, there is sufficient ground noise to drive the stack when rigidly attached to our vacuum tank mounting posts. Only two transfer functions were taken in this frequency range, the ratio of vertical motion on top to vertical motion at the base, and the same for horizontal motion. These two sets of data approximate T_{zz} and T_{xx}, but do not take into account the contribution of the cross coupling terms on the signal on top. Since we have no easy way of making the measurement with two different drive vectors of ground noise, which is what would be necessary to discriminate the four components, only two traces appear below 20 Hz in the transfer function plot of the all-Fluorel stack, Fig. 2(a). The Fluorel-RTV stack has somewhat lower normal mode frequencies, and begins to isolate well at lower frequencies, as can be seen in Fig. 2(b), so the cutoff for these low-frequency measurements was lower.

3. High-frequency cantilever measurements:

In the highest frequency range, above 90 Hz for the all-Fluorel, and 60 Hz for the Fluorel-RTV, it becomes difficult to take data using the first method. The accelerometers we use (Endevco model 7707-1000) exhibit a slight response to magnetic fields; this becomes important when we wish to measure transmission of 10^{-5} or lower, due to pickup from the motor coils. In addition, the noise floor of our accelerometer amplifiers becomes significant at about this level. We solve this problem by providing mechanical amplification at the accelerometer mounting on the top table, by mounting the accelerometer on the end of an aluminum cantilever. The length (and thus the resonant frequency) is adjusted while under vacuum via remote-control motors. This assembly was mounted on the top table, in place of the simple accelerometer. For each frequency point, the cantilever length was adjusted to the correct length, and clamped. The appropriate



(a)

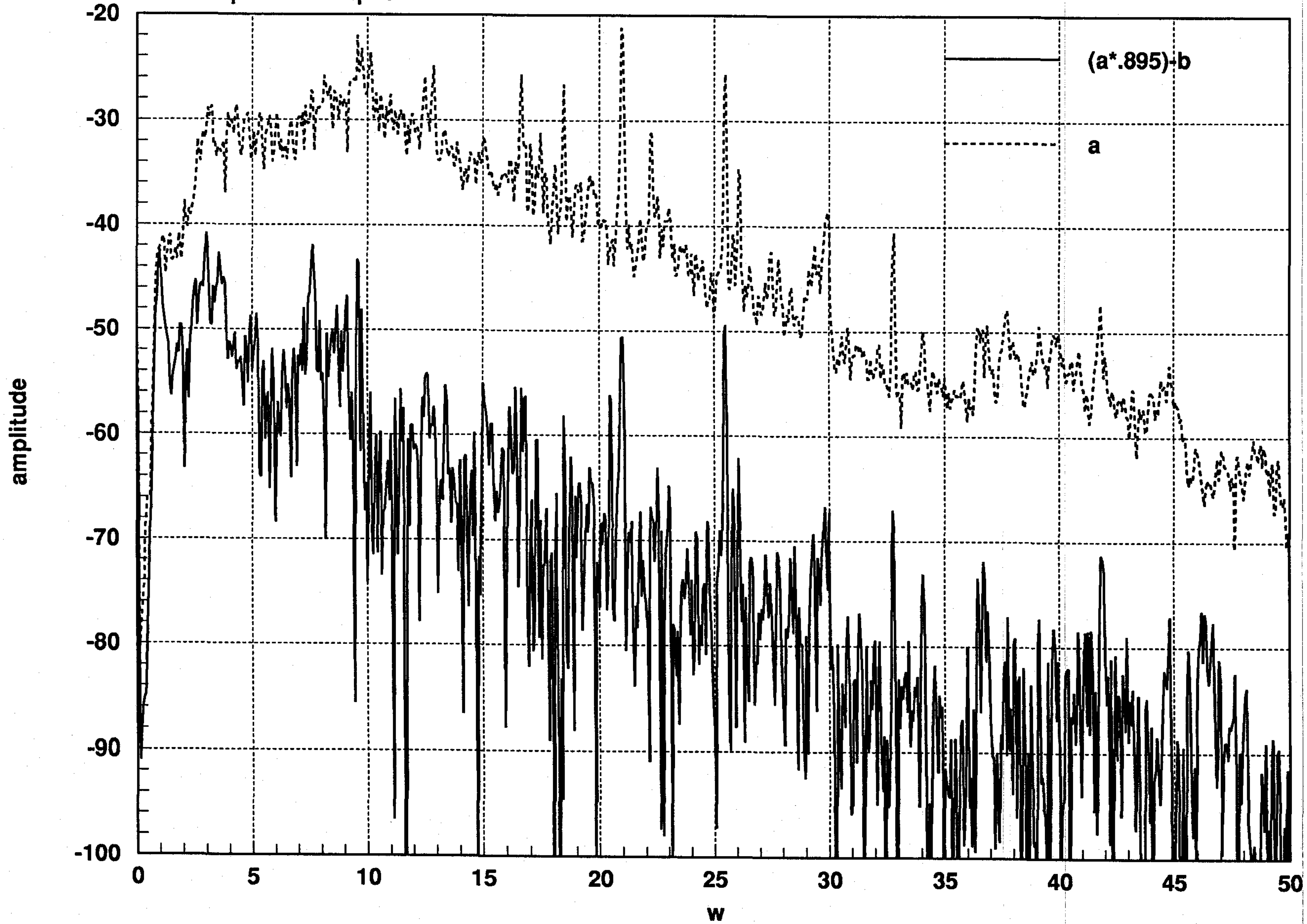


(b)

FIG. 2. Measured transmission matrix elements for (a) the stack built with all Fluorel springs, and (b), built with two lower layers of Fluorel springs and two upper layers of RTV springs.

Top Plate

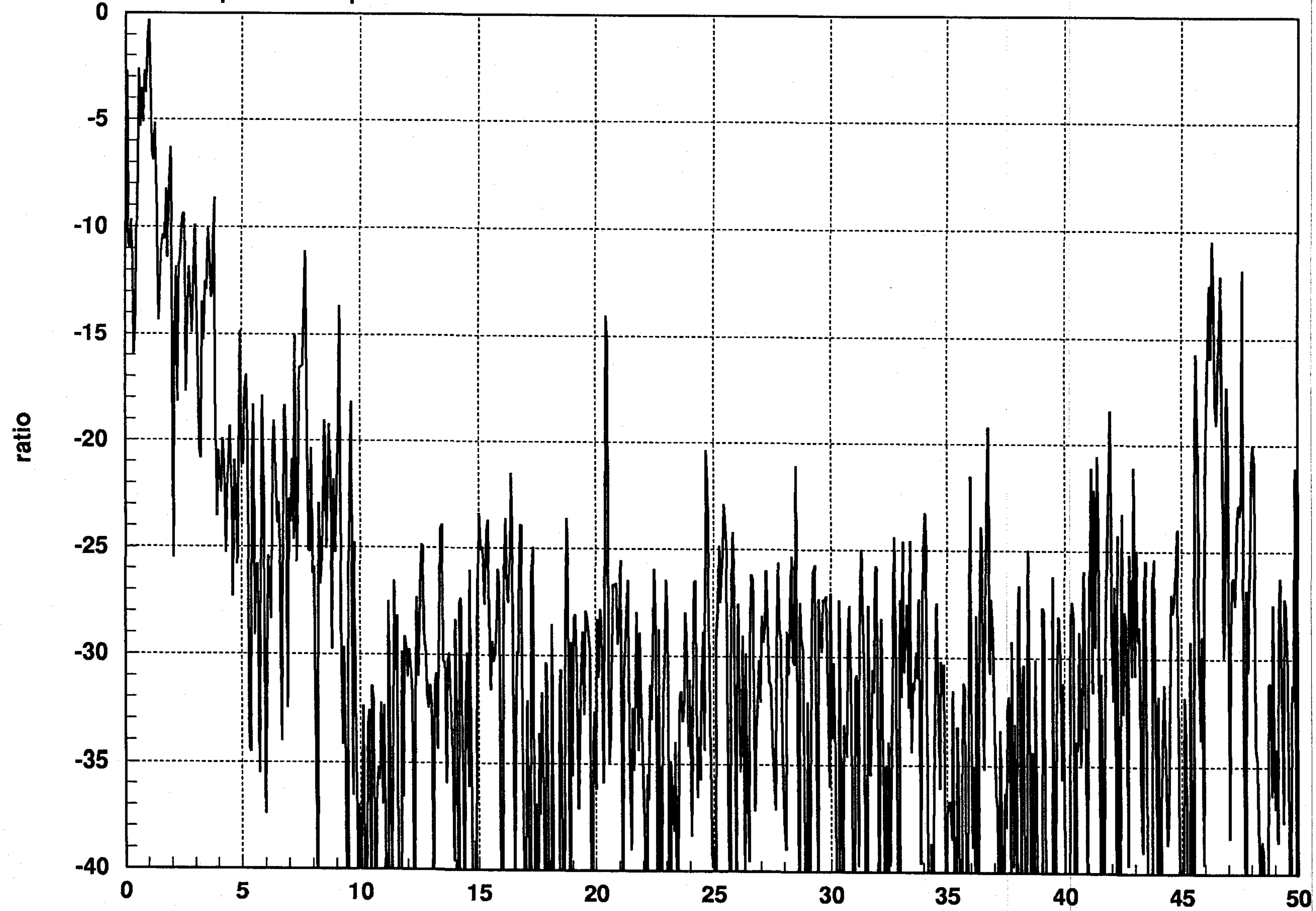
files: eetp19 and eetp20



plots of a and (a*.895-b)

Top Plate

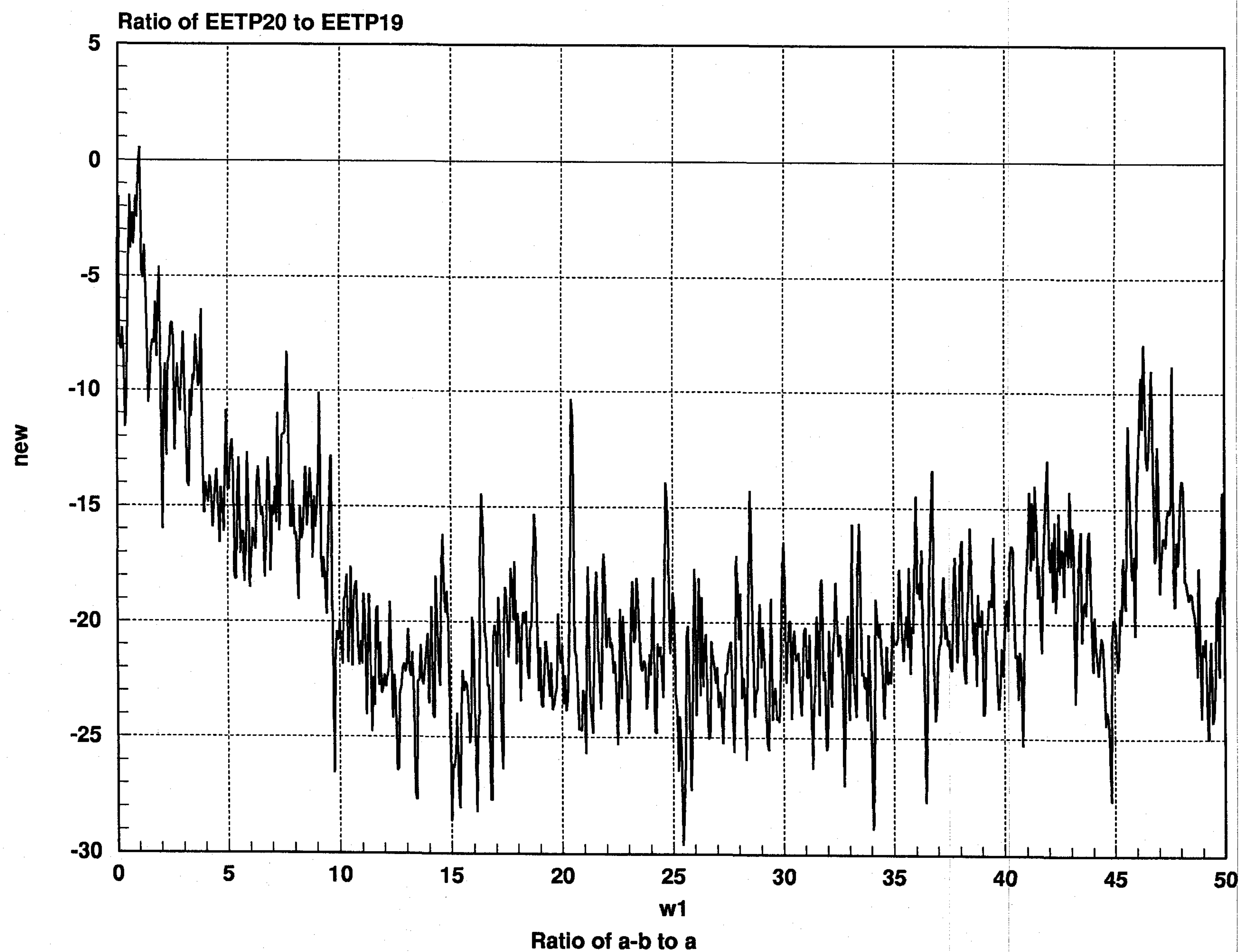
files: eetp19 and eetp20



Ratio of (a*.895-b) to a

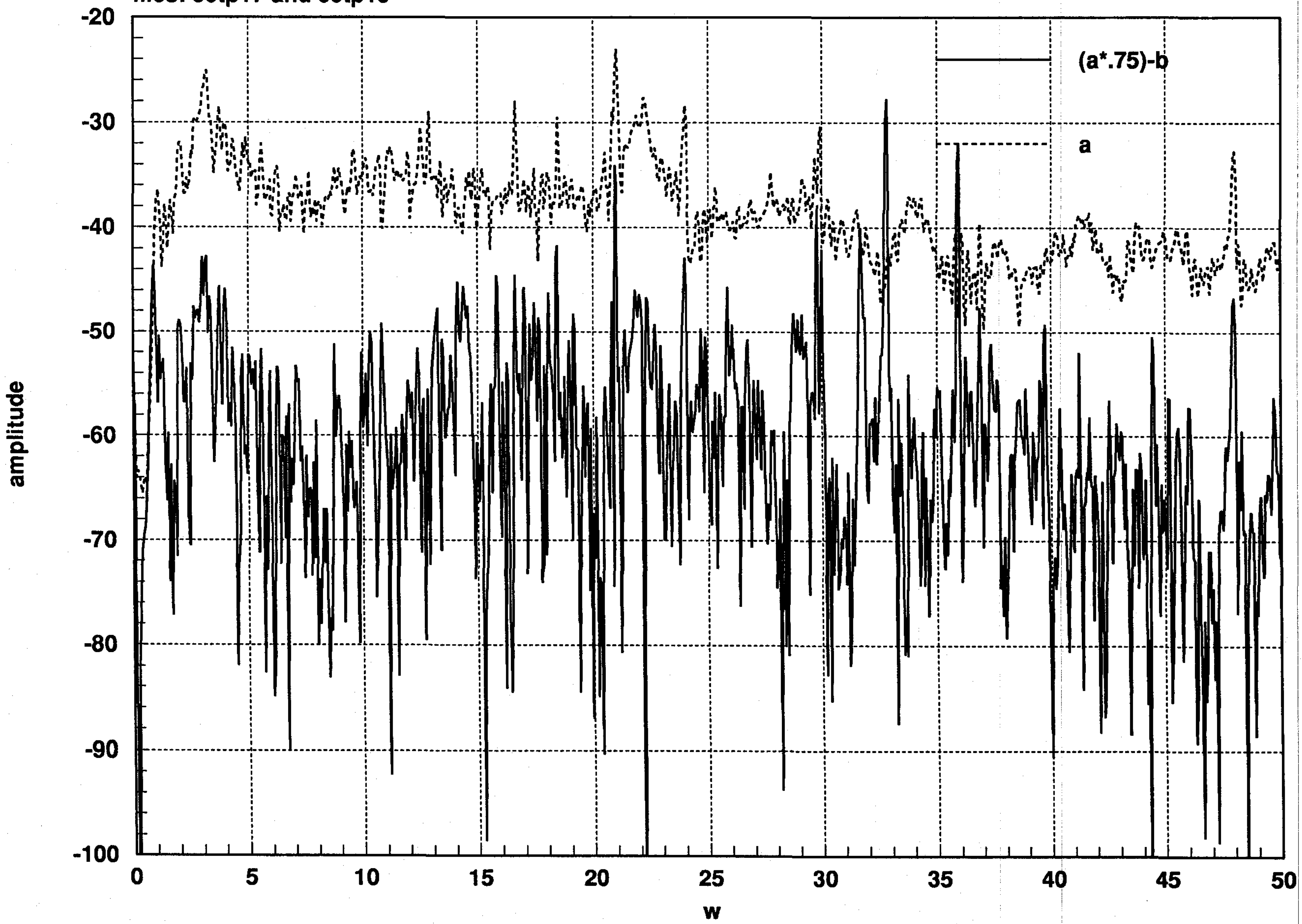
Top Plate

b2b-odb



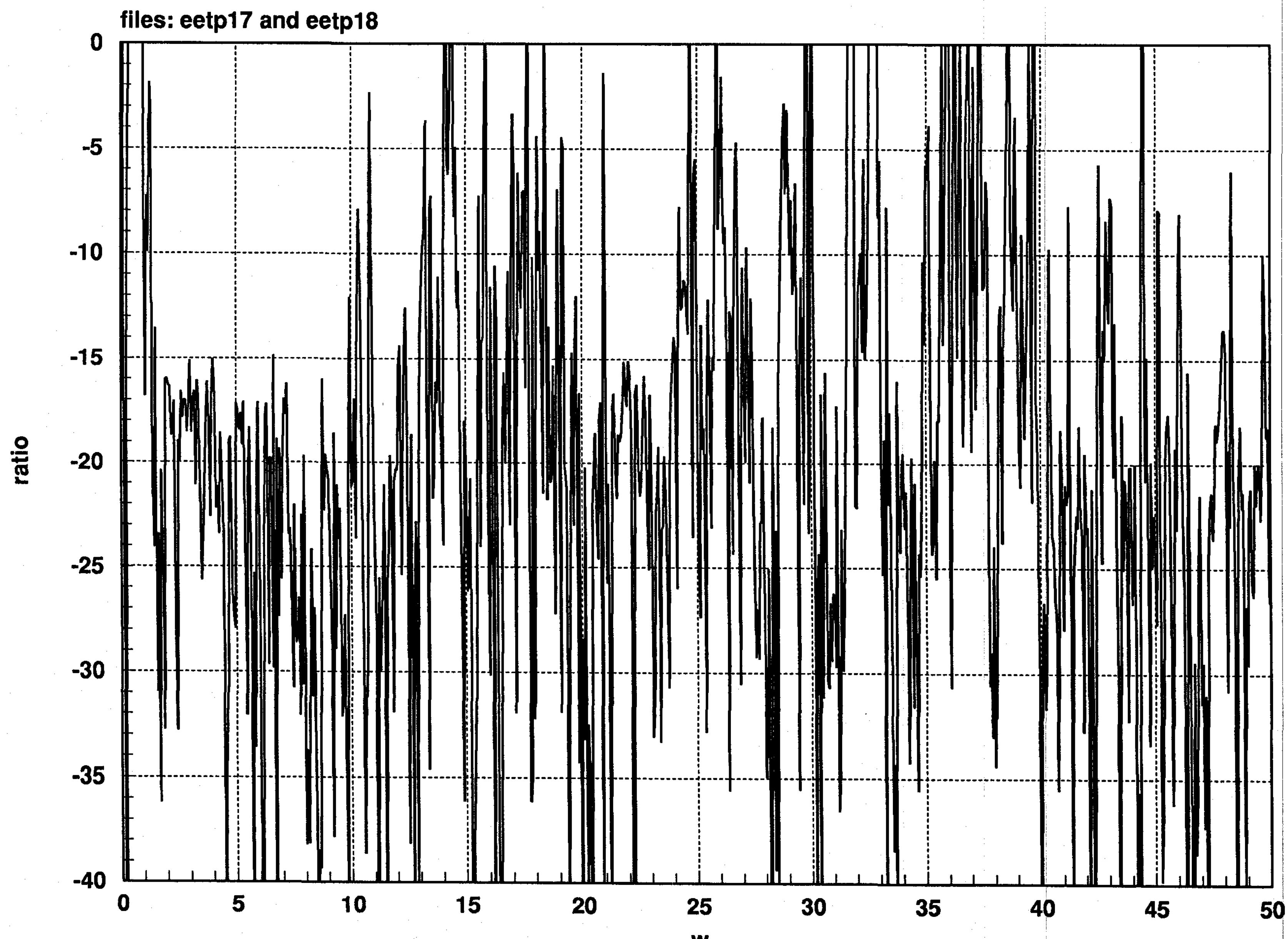
Ground Noise

files: eetp17 and eetp18



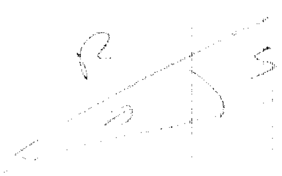
plots of a and (a*.75-b)

Ground Noise



Ratio of (a*.75-b) to a

$S = \theta R$



$$\frac{X_{Tilt}}{XR} = \frac{Z_1 - Z_2}{D}$$

$$\frac{\theta_{TP}}{D_g} = \frac{Z_{MP} - Z_{TP}}{Z_G - Z_G}$$

Seismic isolation and suspensions
(Giaime, Shoemaker, Spero, Raab, Gillespie, Sievers, Saulson, Stebbins)

a) Overview of the seismic isolation and suspension requirements for the initial LIGO interferometer: seismic noise contribution to the test mass motion, rms motion permitted, long term length and tilt stability required.
Overview of the thermal noise requirements for the initial interferometer; pendulum and test mass internal modes.
(Raab, 40 min)

b) Passive vibration isolation stacks: analysis, transmssion measurements, transmssion by cabling, adaptation for 40 meter system, improvements with rtv springs. (Giaime, Shoemaker, Sievers, 30 min)

c) Vacuum and contamination compatibility of elastomers: rga measurements, optical contamination cavity measurments
(Raab or equivalent, 20 min)

d) Measurements of suspension isolation in 40 meter suspensions
Anticipated seismic spectrum in Mark II 40 meter system
(Spero, 20 min)

d') Visit 40 m stacks and suspensions (Sievers/Spero, 30 min)

e) Thermal noise studies: Pendulum string modes and predictions for pendulum thermal noise in suspension for mark II 40 meter system.
(Gillespie, Raab, 30 min)

f) Test mass thermal noise: current state of analysis and Q measurments, projections for 40 meter system, (information on the low Q modes?) losses from magnets, losses from wires, losses at attachments.
(Gillespie, Raab, 30 min)

g) Off resonance thermal noise studies in fused quartz (Kovalik experiment)
(Shoemaker, 10 min)

ef') Visit to Optics lab suspension development (Gillespie/Raab, 30 min)

h) Work at Syracuse (Saulson, 40 min)

i) Summary of work by Braginsky (Spero, 20 min)

j) Active isolation systems (Stebbins, 40 min)

k) Summary of progress and plans to meet requirements for vibration isolation and thermal noise (suspension and test mass modes) for the initial interferometer. (Raab, 20 min)

Total time 6 hours

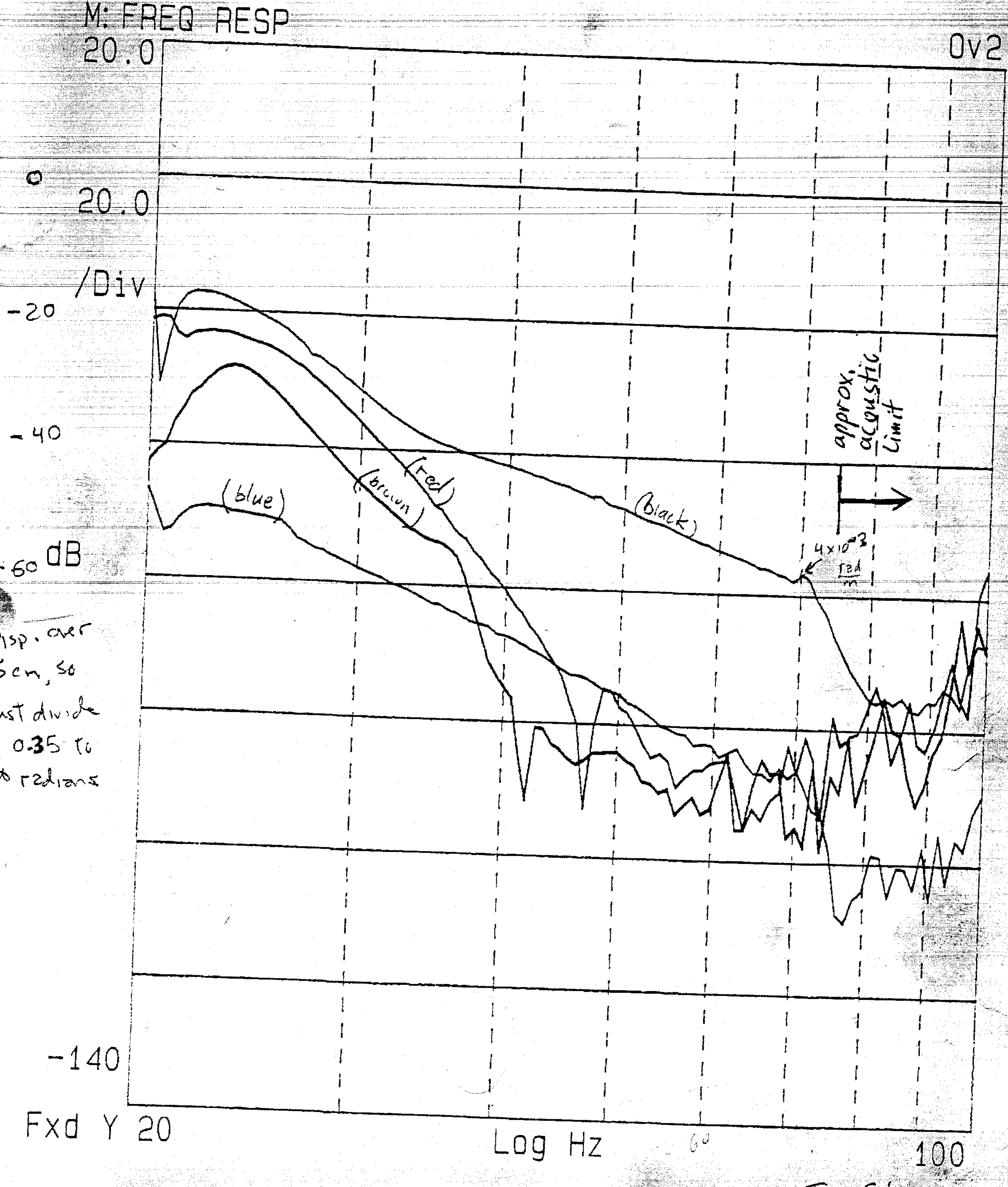
Measured in AIR

$\phi_x \to$ rock

$\phi_z \to$ twist

$\phi_x \cong x$

ϕ_z^{top} vs x^{boc}	black	— NS77 - 40dB
ϕ_x^{top} vs z_e^{boc}	blue	— NS78 - 40dB
ϕ_z^{top} vs z^{boc}	red	— NS 58 - 40dB
	brown	— NS 59 - 40dB



Disp. over 35 cm, so must divide by 0.35 to get radians

J. Giaime
11-5-91

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Gravitation and Cosmology Research Group
Cambridge, Massachusetts 02139

MIT GRAVITY GRP. FAX #617-253-7014
CONFIRMATION # 617-253-4824

Facsimile Cover Sheet

DATE: 11-5-91 TIME: 5 PM (E.T.)

TO: LISA SIEVERS FAX#:

ADDRESS:

NUMBER OF PAGES (including this cover sheet): 4

FROM: Joe Giaime OFFICE #: (617)253-0203
Massachusetts Institute of Technology
Room 20B–145
Cambridge, Massachusetts 02139

NOTES:
(see next page)
- electrical cross talk
- magnetic coupling
- vacuum not tight enough

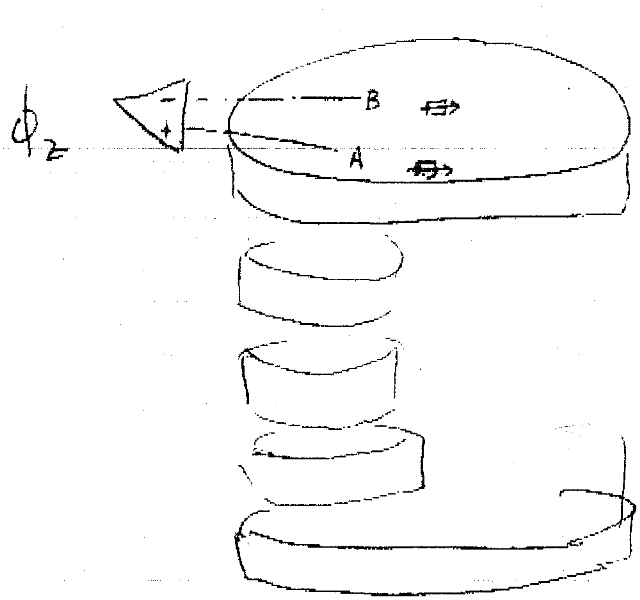
11-5-91

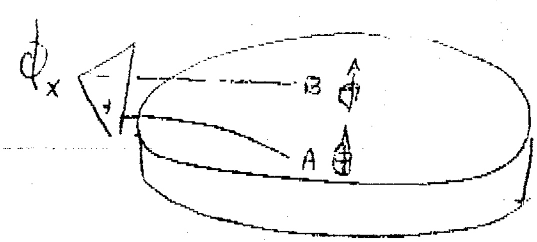
Lisa,

Here are some of the data.

The first plot, from 20-200 Hz, shows the four transfer function elements, measured at the outer edge of the top table & drive table. These were measured in vacuum, and the electronic noise floor was ≈ -100 dB

The second plot runs from 20-100 Hz, and was from air measurements. I have marked the approximate point where the acoustic coupling became important. These transfer functions were of the setup drawn below, shown for each ϕ. The "lever arm" ~~to~~ between A & B was ~15 cm



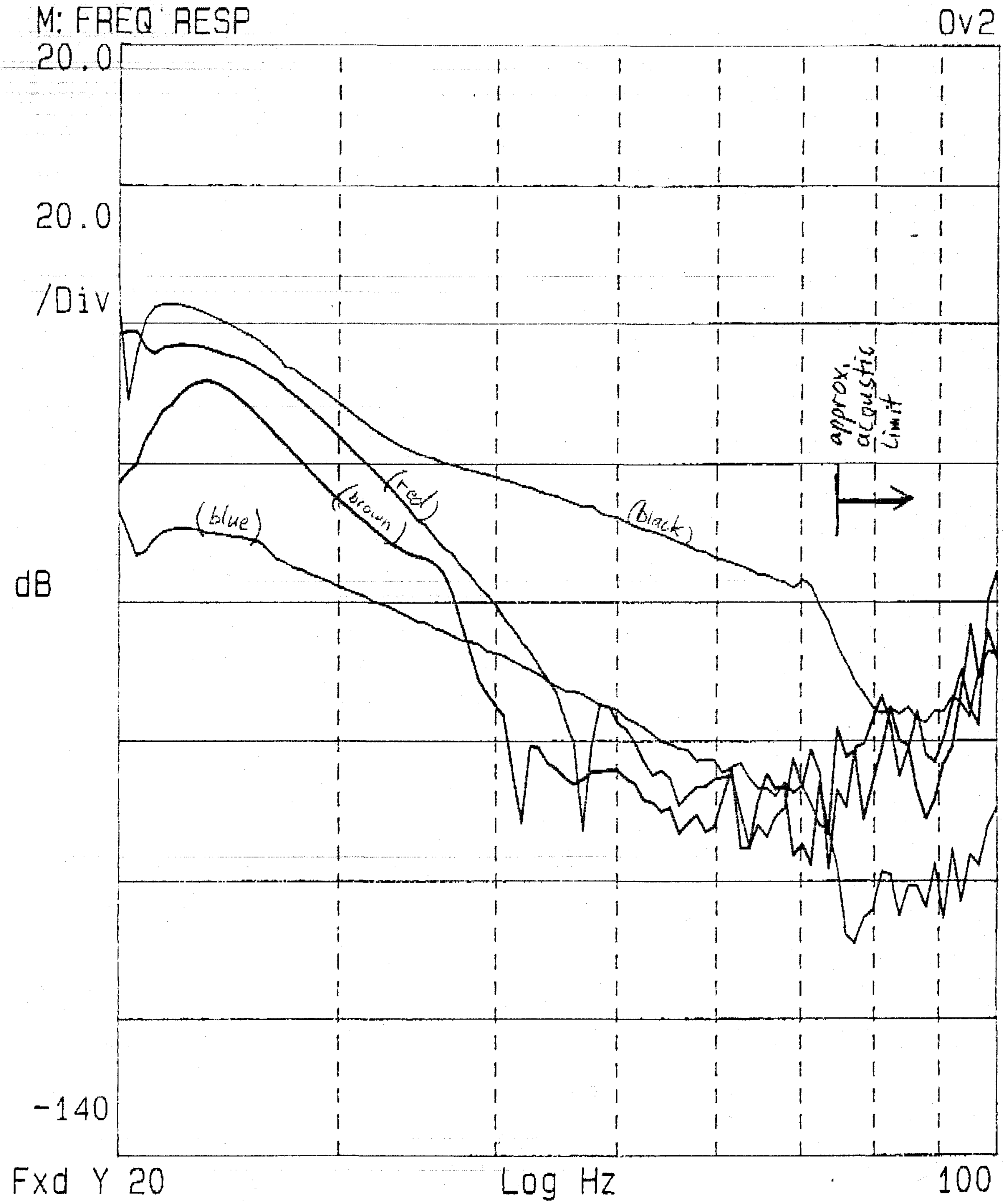


— Joe

Measured in AIR

$\phi_x \to$ rock
$\phi_z \to$ twist

ϕ_x vs x^{bot}	black	NS77	-40dB
ϕ_z^{top} vs x^{bot}	blue	NS78	-40dB
ϕ_x^{top} vs z^{bot}	red	NS 58	-40dB
ϕ_z^{top} vs z^{bot}	brown	NS 59	-40dB



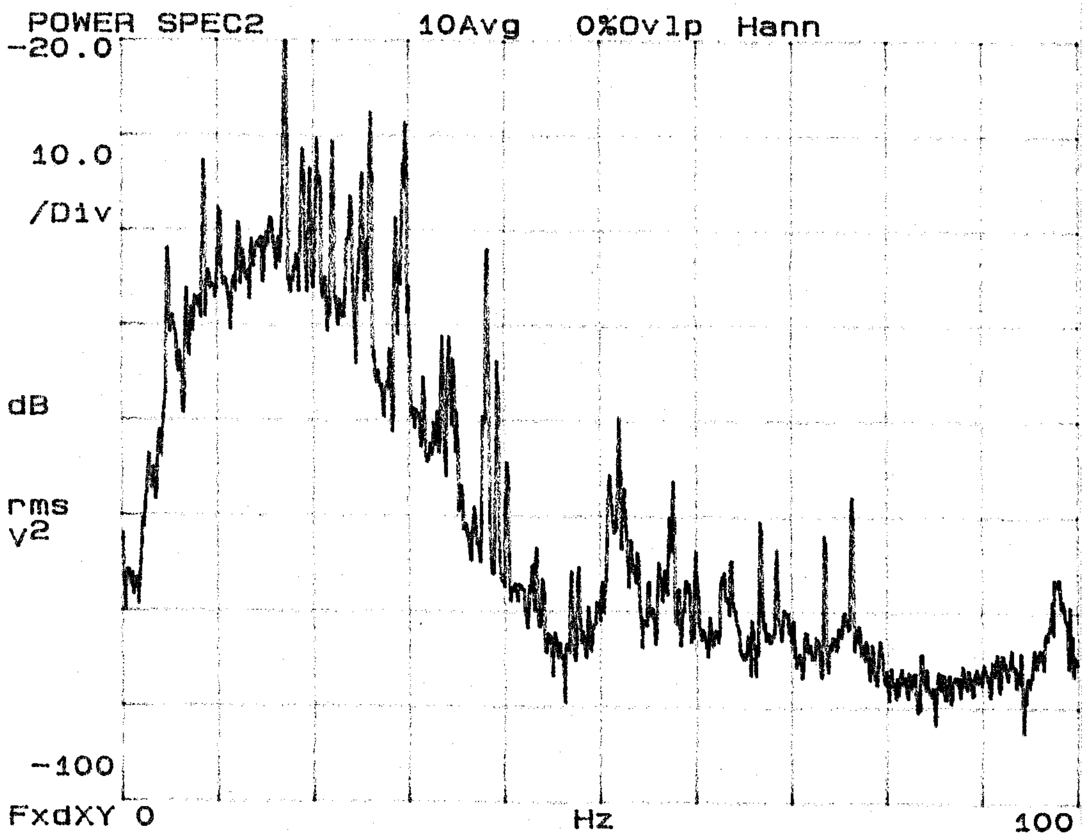
J. Giaime
11-5-91

BATCH START

STACKS BOOK 2

STAPLE OR DIVIDER

Q5



2/11/93 4:50 PM

Power Spectrum of accel in vertical position on Al Plate

- All rotor stack (8, 2, 46)
- Used gray noise excitation

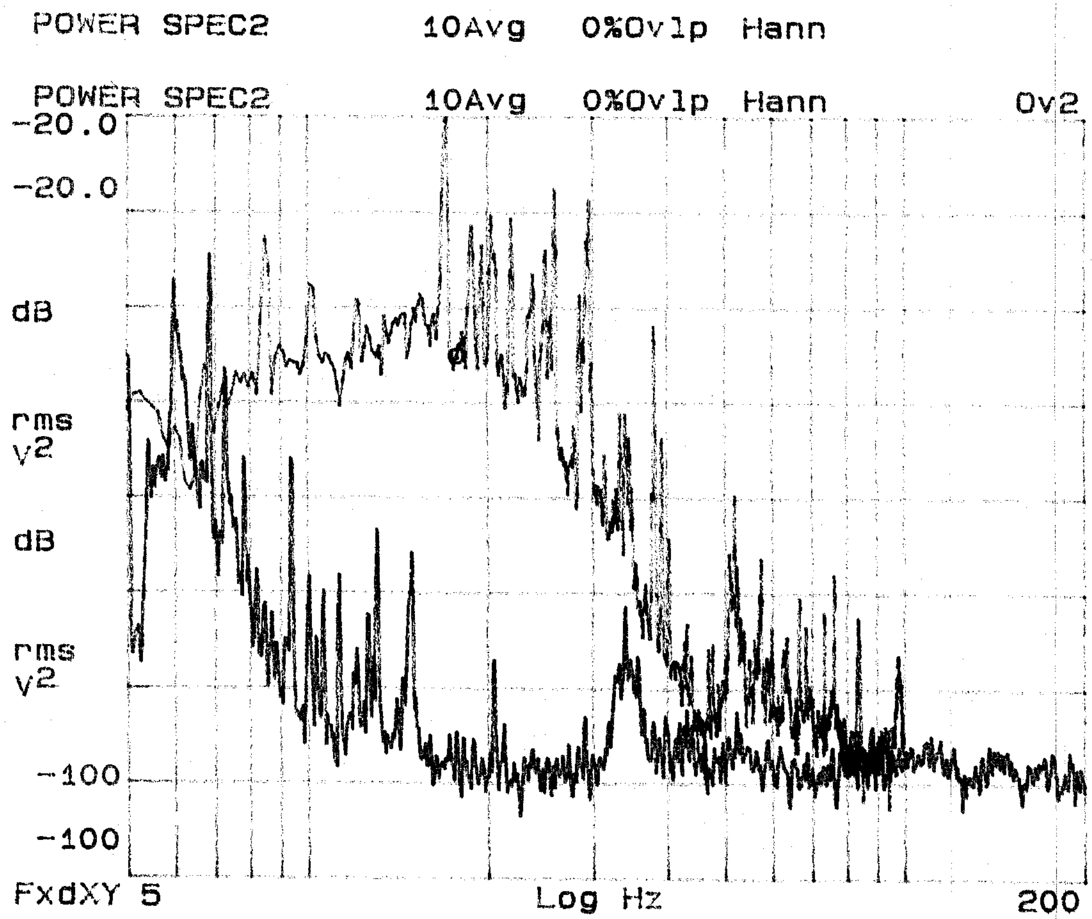
2/11/93 4:50 PM

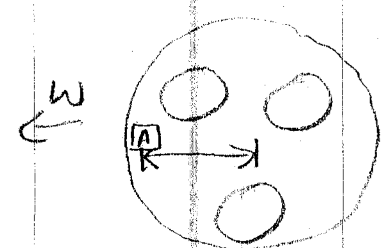
Power spectrum of accel in vert. and in horiz. position on A1 plate

- All vitor stacks (8-6-4-2)
- Used ground noise excitation

Q6

X=17.87 Hz
Ya=-45.271 dBVrms



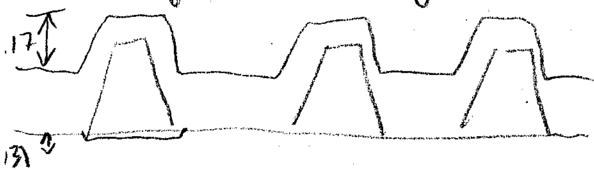


Oct. 21, 1992

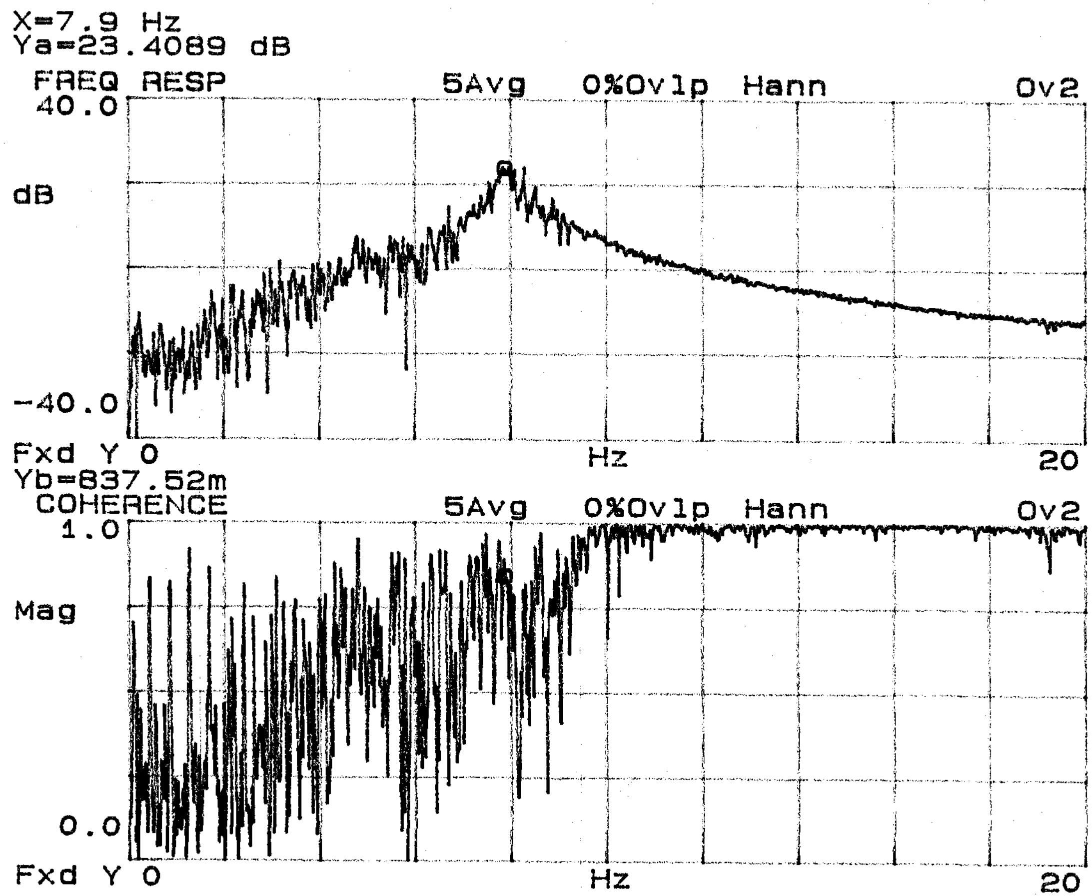
<u>RTV Springs tests to determine stiffness under different loading</u>

V-V Transfer function of spring mass for RIV
Oct 21, 1992
3:45 PM

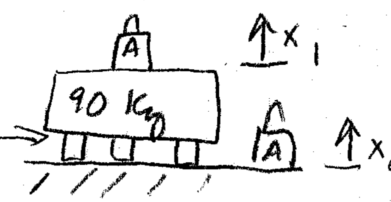
springs are compressed by 8%



↕ .715", .710", .705"

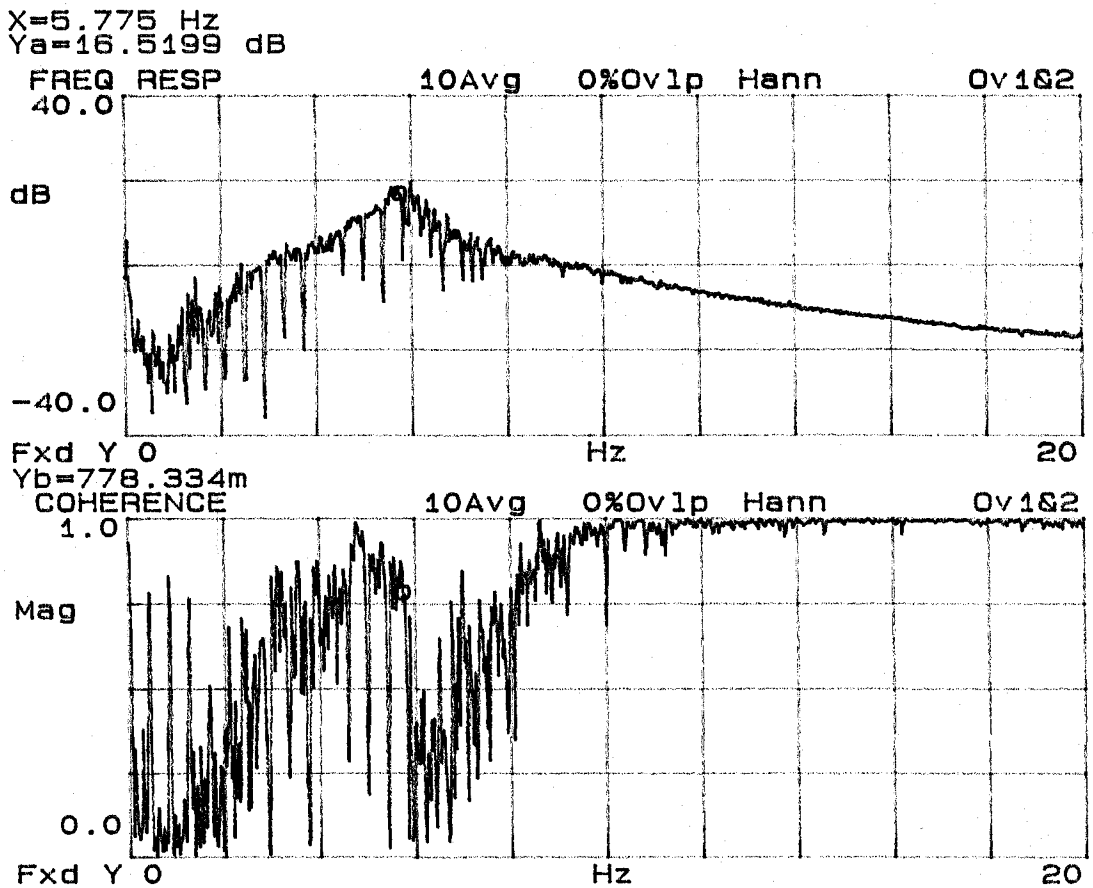


- ground noise excitation



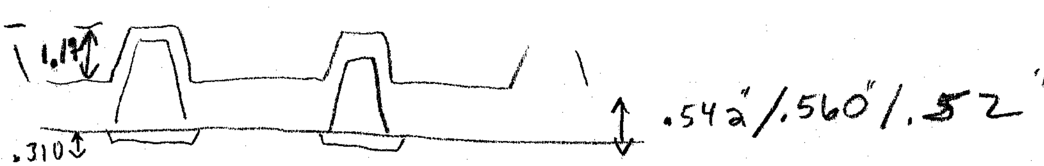
springs:
conical design to be used in Mark II

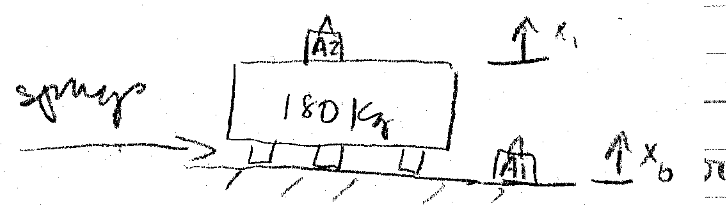
V-V transfer fctn of
spring mass for RTT
Oct 21, 1992
4:00 PM



- Testing conical springs to be used in Mark II
- ground noise excitation

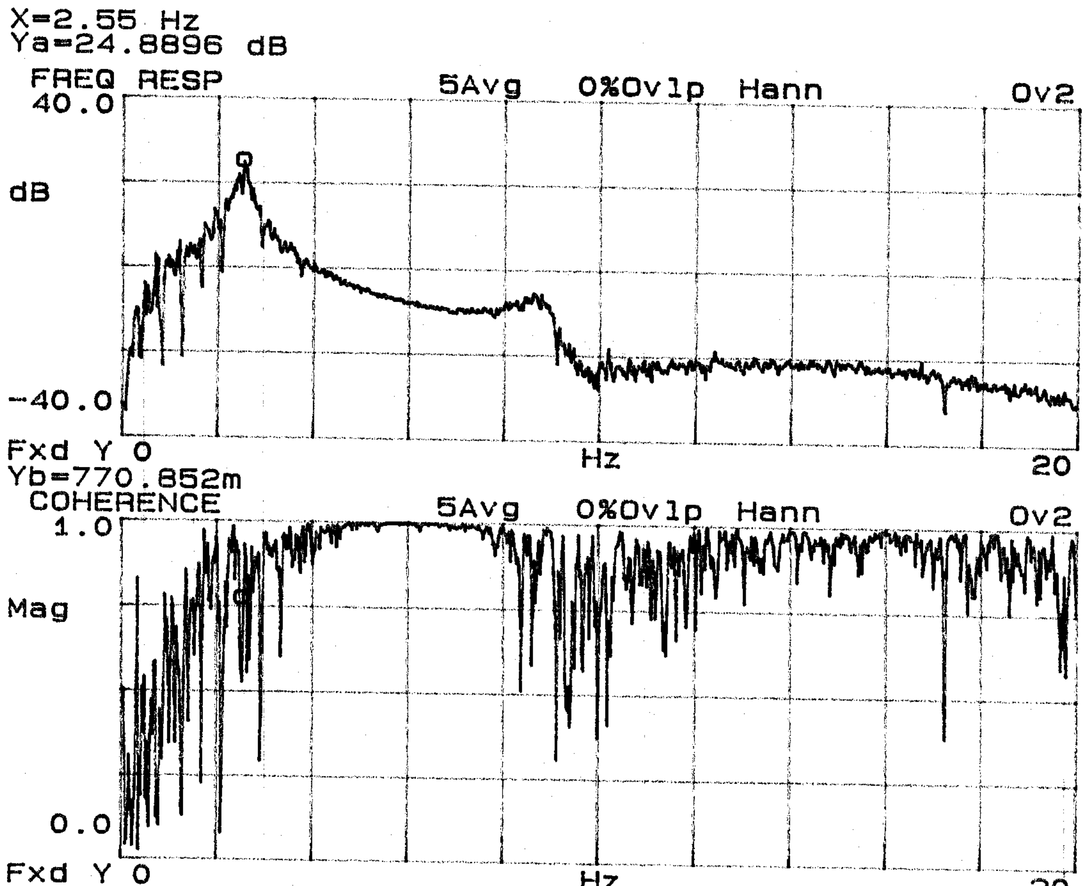
- Springs are compressed by 17%



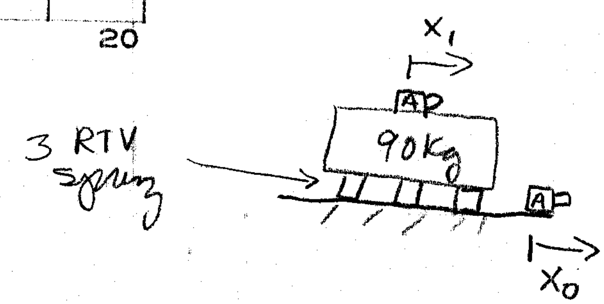


Transfer function of spring-mass for RTV

Oct 21, 1992
3:30 PM



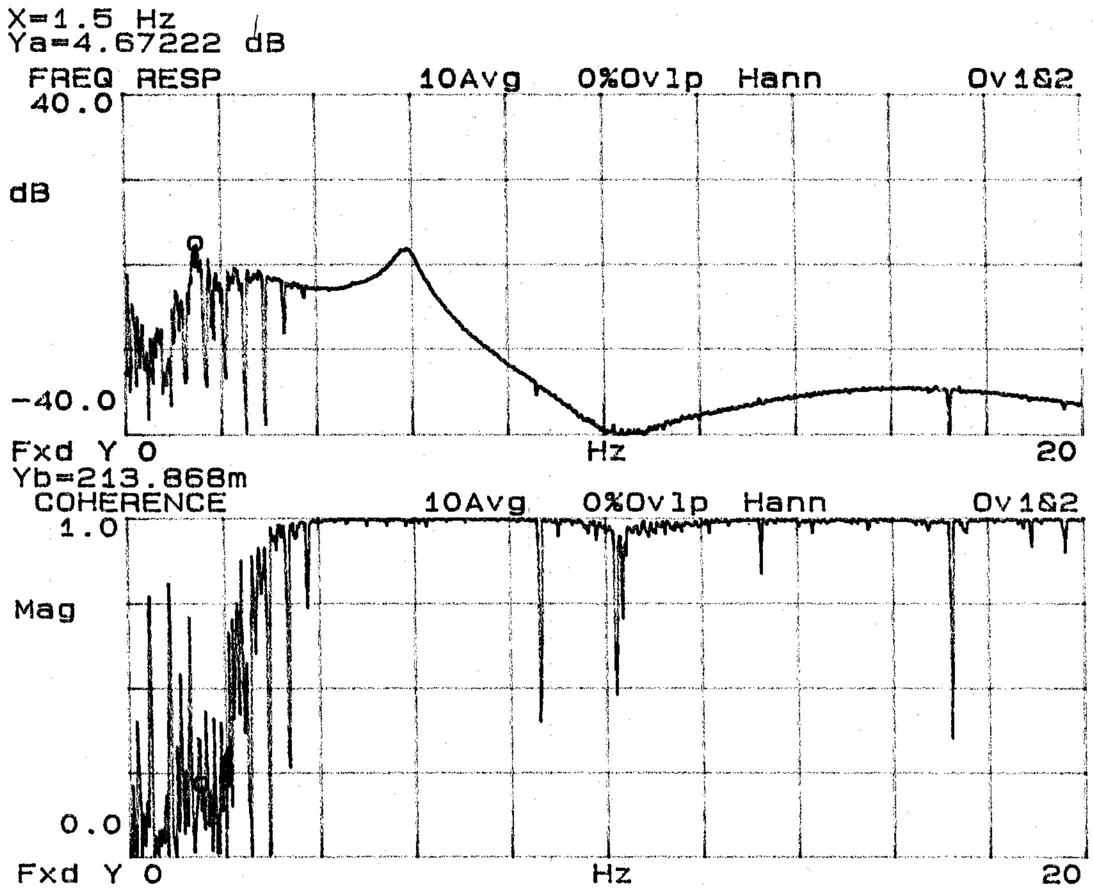
- ground noise excitation



imp:
Conical design to be used in Mark II

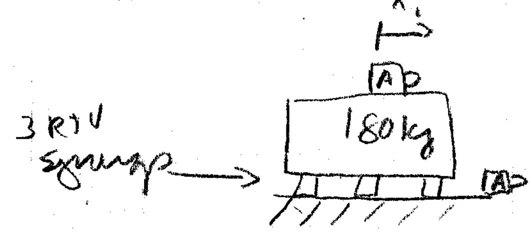
Transfer function of spring-mass for RIV

Oct 21, 1992



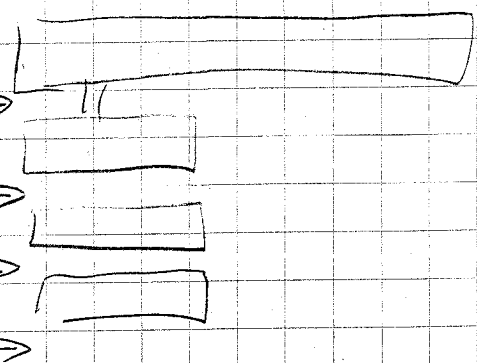
– ground noise excited

springs:
Conical design to be used in Mark II

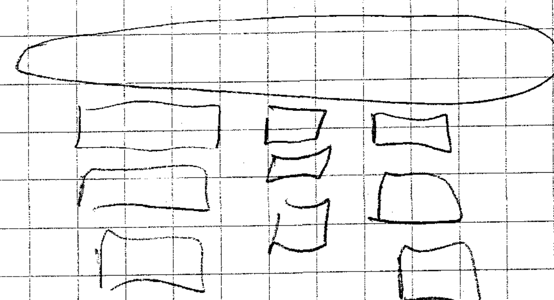


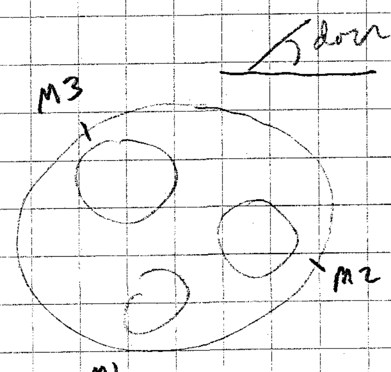
Stack Tests

Set up stacks with 4 layers of viton



Height of stack





	M1	M2	M3
Oct 22	20 13/16	20 13/16	20 14/16
Oct 26	20 6.5/16	20 9/16	20 7/16
Nov 3	20 1/4	20 5/16	20 6/16