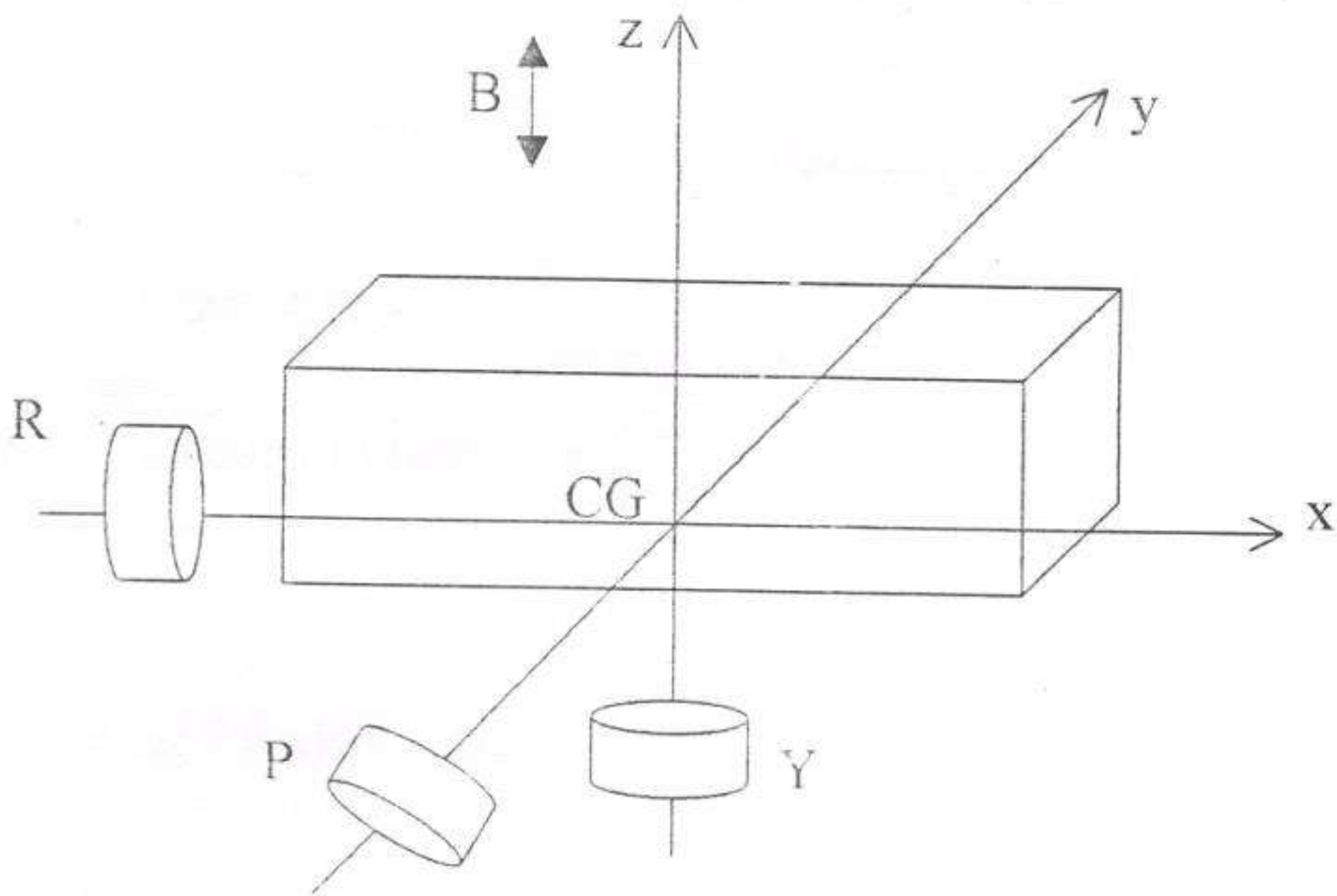
Testing of Coaching Stock

Need for Testing New Stock

- **Safe new design**
- Get natural frequency in various modes
- **Ensure level of comfort**
- Statutory requirements as per Policy Circular No 6 of Rly. Bd.

Modes of Oscillation



Policy Circular No 6

- No.92/CEDO/SR/4/0 dated 23/12/1999 issued by Member(Engg), Rly.Bd.
- Contains rules for certification of maximum permissible speeds for rolling stock
- Rly.Bd. is safety controlling authority for Indian Railways under Indian Railways Act
- Responsibility delegated to RDSO
  - Determine & recommend max permissible speed for new design rolling stock

Policy Circular No 6(contd.)

- Definition of new rolling stock
  - Different principal dimensions
  - Different bogie design
  - New braking system
  - Change in axle load, track loading density, unsprung mass
  - Minor changes in design,internal layout(with sanction of CRS) only if leading to significant change in
    - C.G.,Weight distribution, ride behaviour

Policy Circular No 6(contd.)

- Types of trials -new stock
  - Detailed oscillation trials (track worthiness trials in AAR)
  - EBD(speed >110 for passenger & 75 for goods) & Coupler force trials of trains
  - Confirmatory oscillograph car run on tracks above 110Kmph
  - Route Proving run between 105-110 Kmph by zonal Rly using portable accelerometers
    - Accel <.3 g or <.25 peaks/km for .3g < accel < .35g

Steps in Track Worthiness Testing

- Develop prototype
- Instrumented runs on track
  - Acquire data
  - at one/many speeds
- Off line analysis of data
  - Compare aggregates/peak values against preset limits
  - Accept or reject stock at that speed

Strategies for Testing of Rolling Stock's Track-worthiness

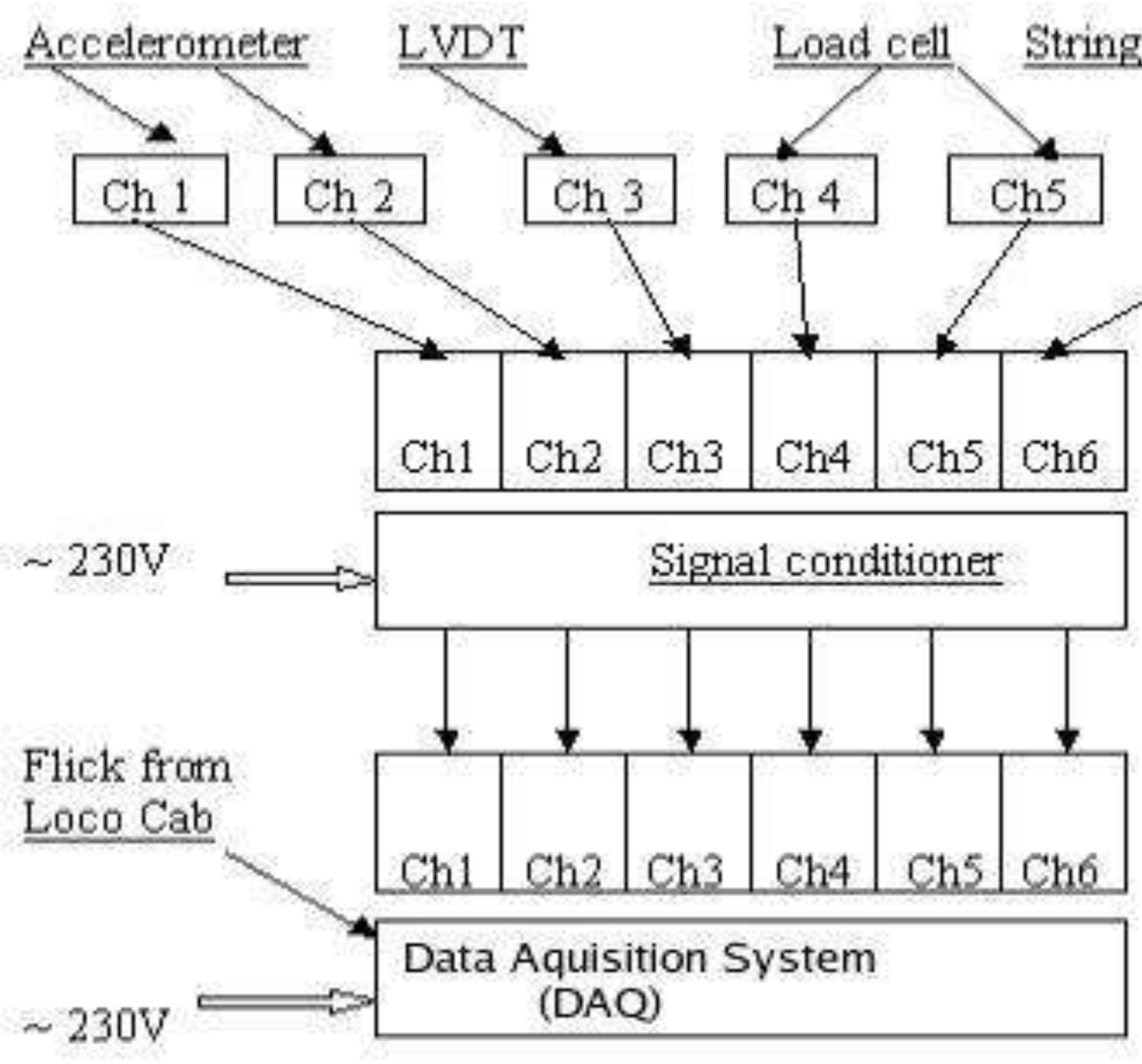
- AAR
  - On dedicated test track
  - Check oscillation behaviour on preset track disturbance
    - Values **unlikely** to occur in actual service conditions
- UIC (covered by leaflet UIC-518)
  - On service track at 10% more than planned speed
  - Cover all types of sections with allowed track values
    - Values **likely** to occur in actual service conditions

Strategies for Testing of Rolling Stock's Track-worthiness (Contd.)

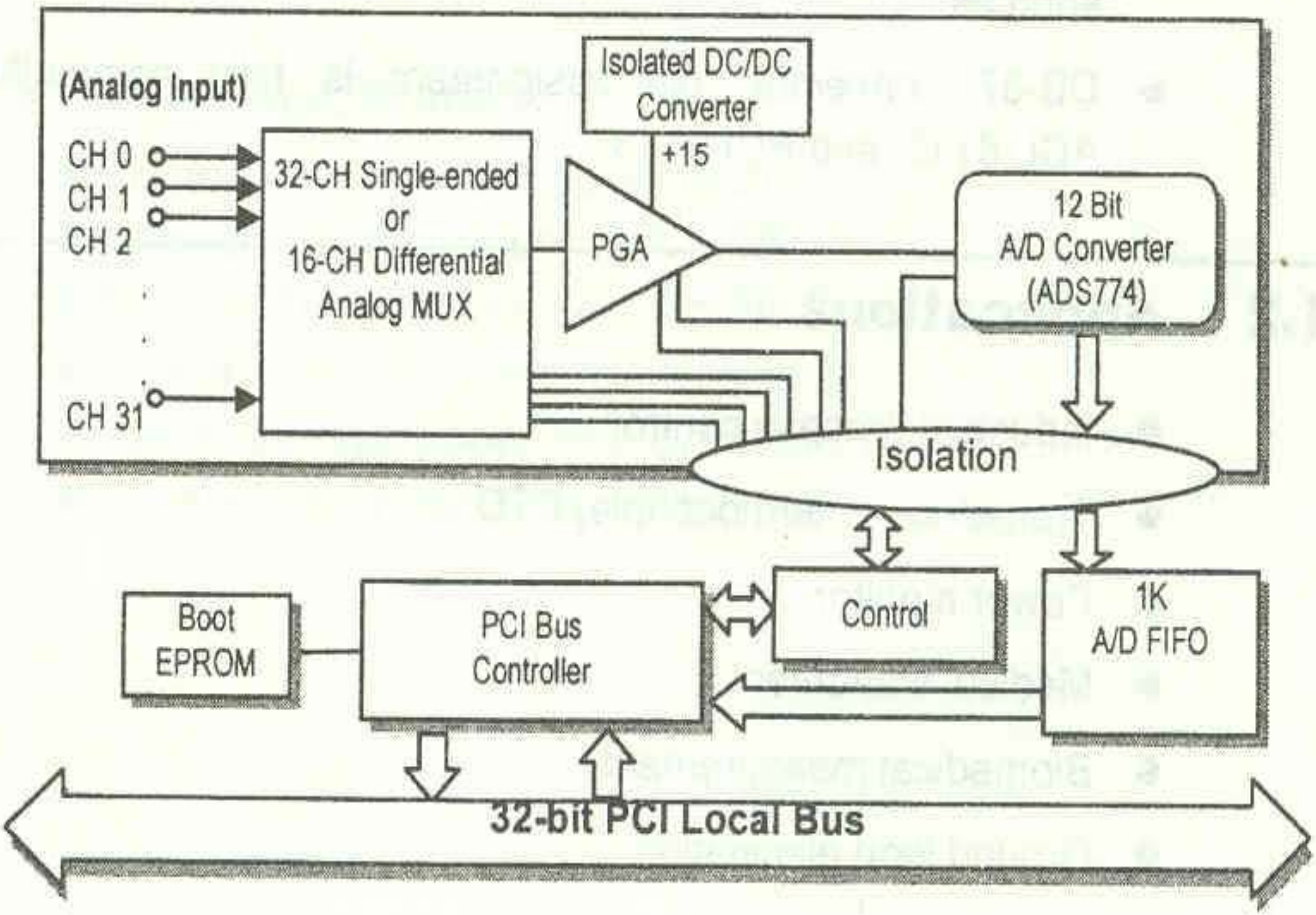
- UIC (contd)
  - Many sections covered including different radii curves
    - Usually 99.85 & 0.15 percentile values/section taken
      - Other values ignored
    - Statistically estimate maximum value from aggregates like mean & standard deviations of the above values
- Indian Railways
  - On actual run down service track at many speeds
    - 90% of track better than this

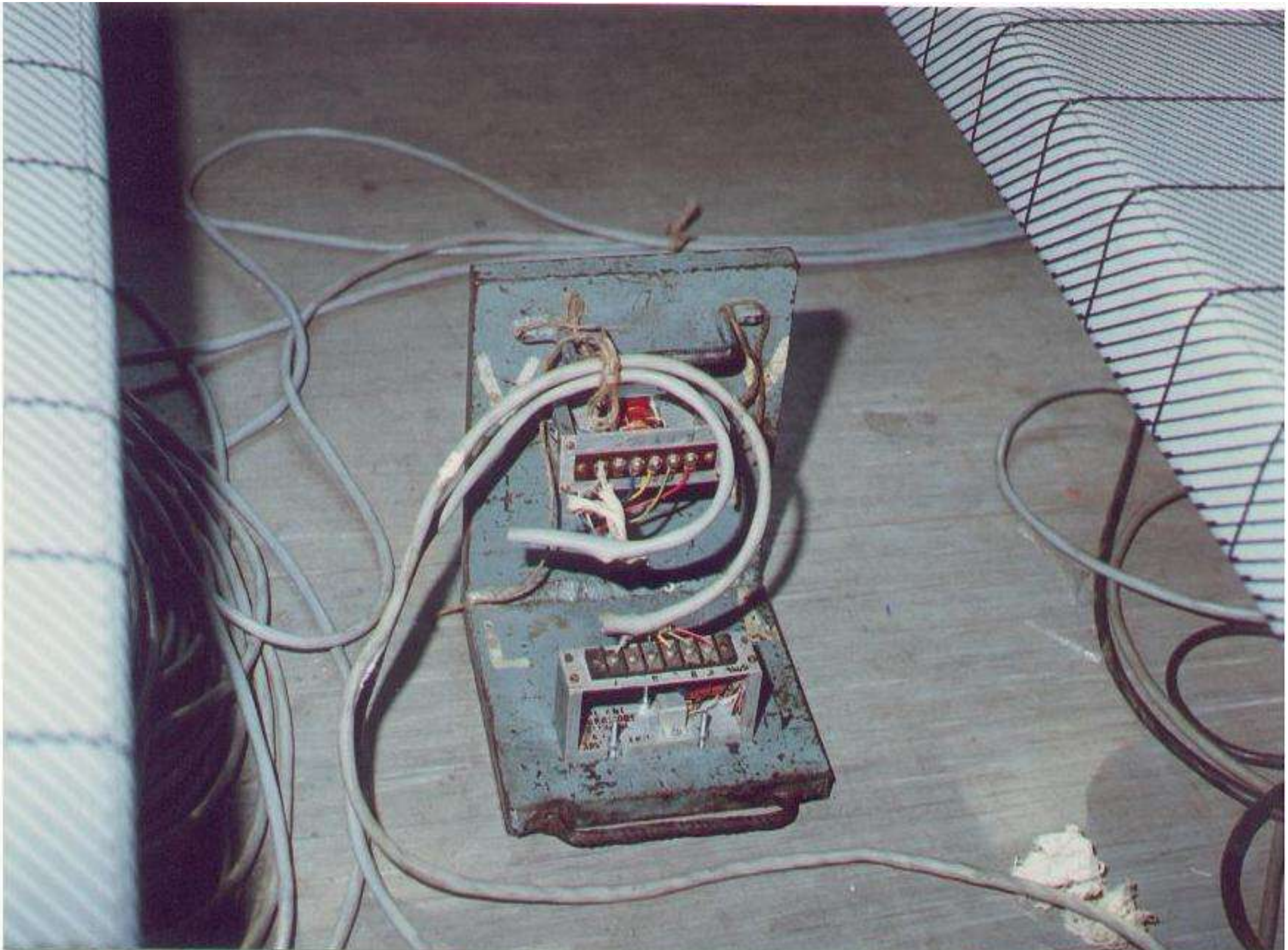
Signal Processing

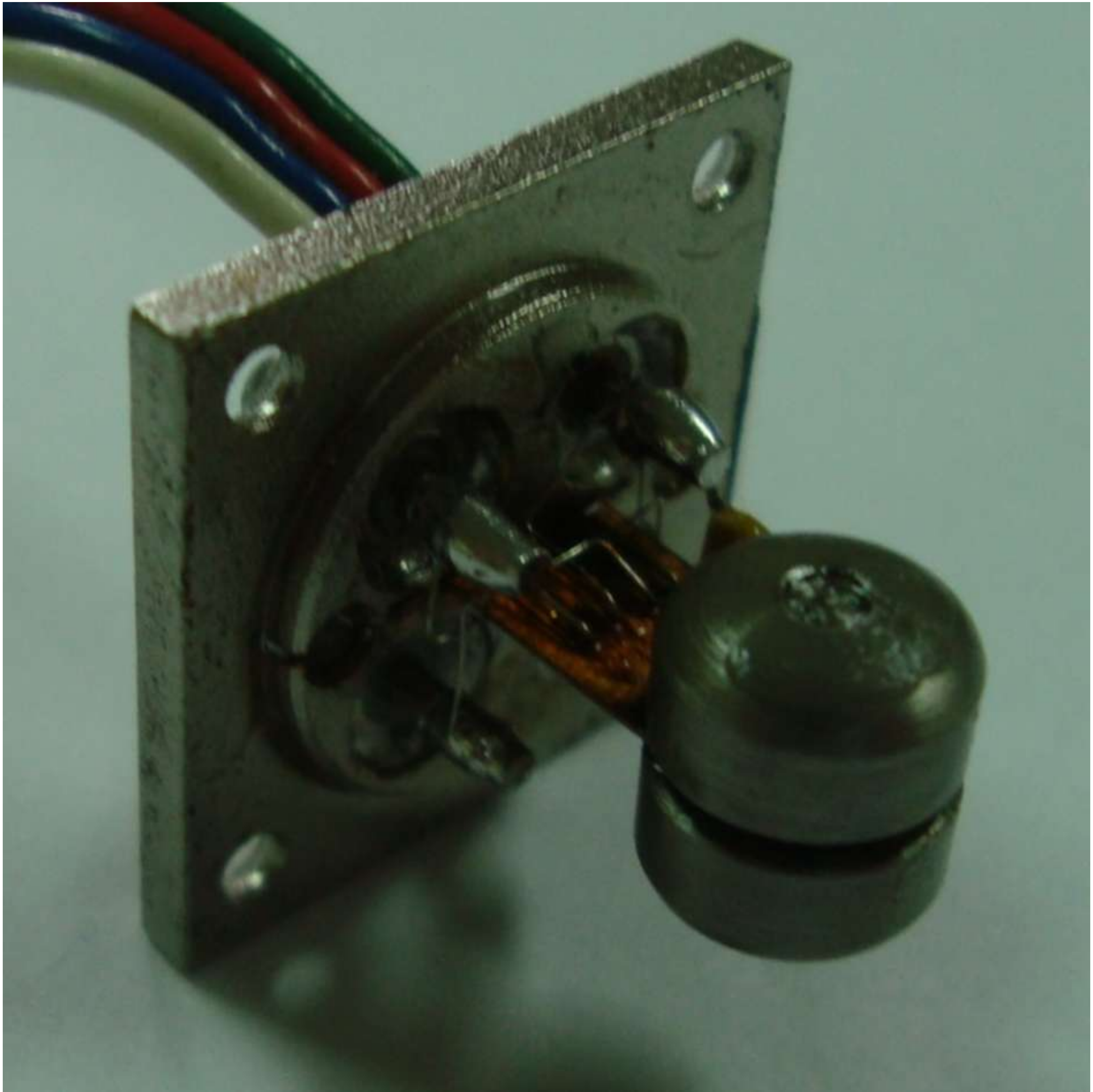
Data Acquisition System



Data Acquisition Card

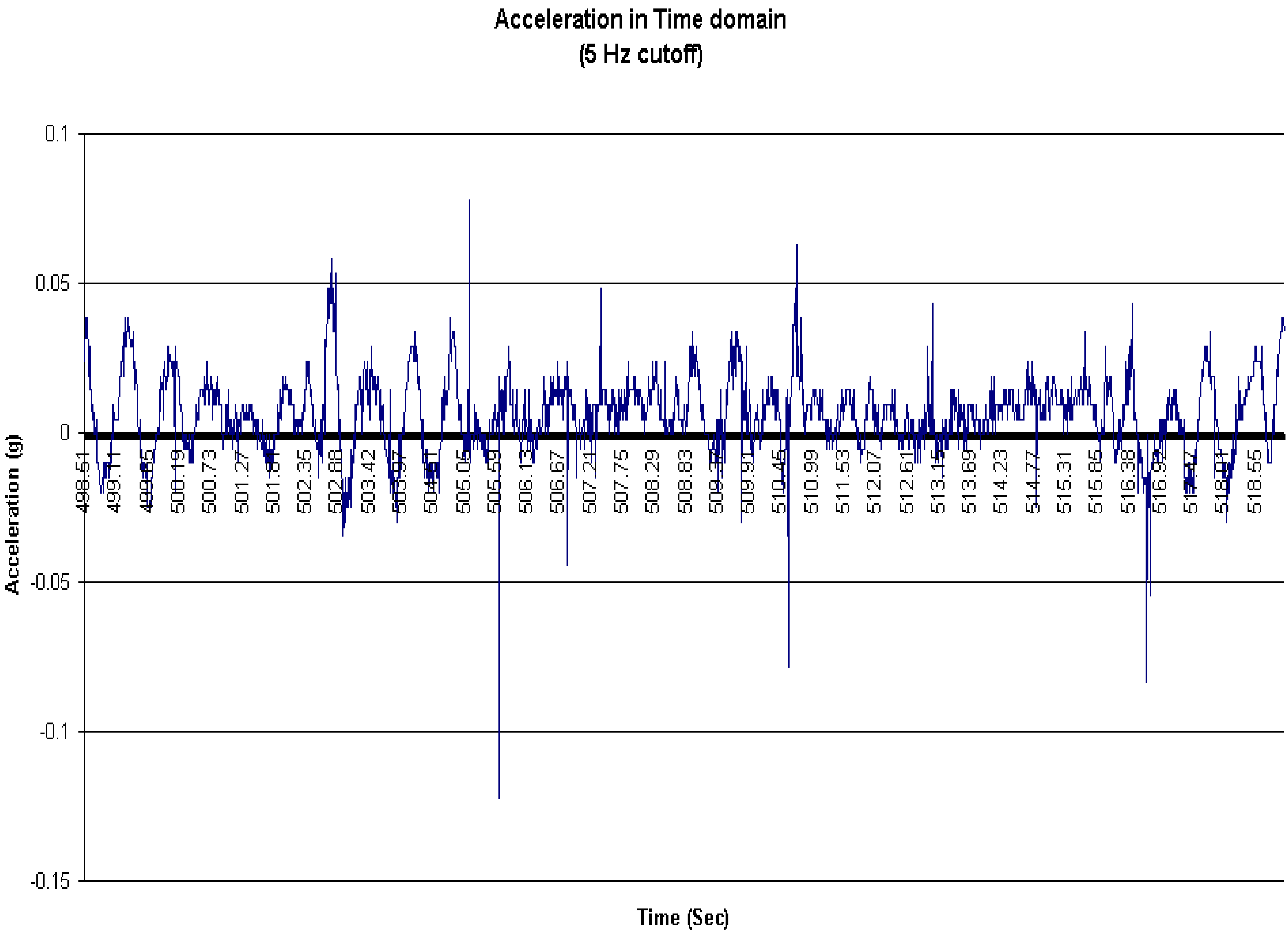


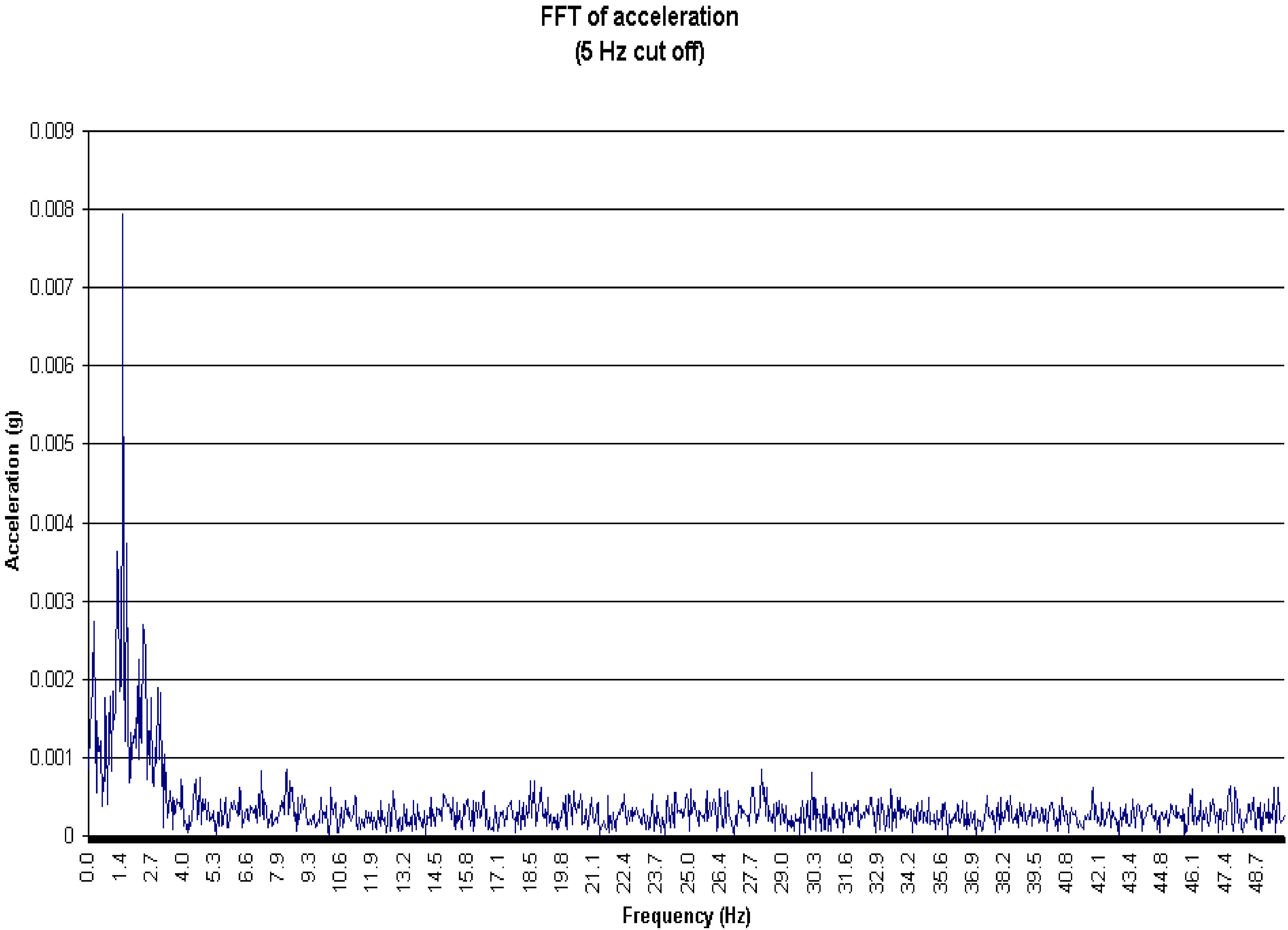




Fourier Transformation

- Orthogonal Transformation of any function
  - As sum of sin waves of various frequencies & phases
- Fast Fourier Transformation
  - Discrete data
  - Uses computationally efficient algorithm
  - Fundamental frequency =1/observation time
  - Usually sum of harmonics of fundamental frequency
  - Highest frequency = ½ sampling rate (Nyquist


Acceleration in Time domain
(5 Hz cutoff)
Acceleration (g)
Time (Sec)
0.1
0.05
0
-0.05
-0.1
-0.15
500.19
500.73
501.27
502.35
503.42
505.05
506.13
506.67
507.75
508.29
508.83
510.99
511.53
512.07
512.61
513.69
514.23
514.77
515.31
515.85
516.38
518.55

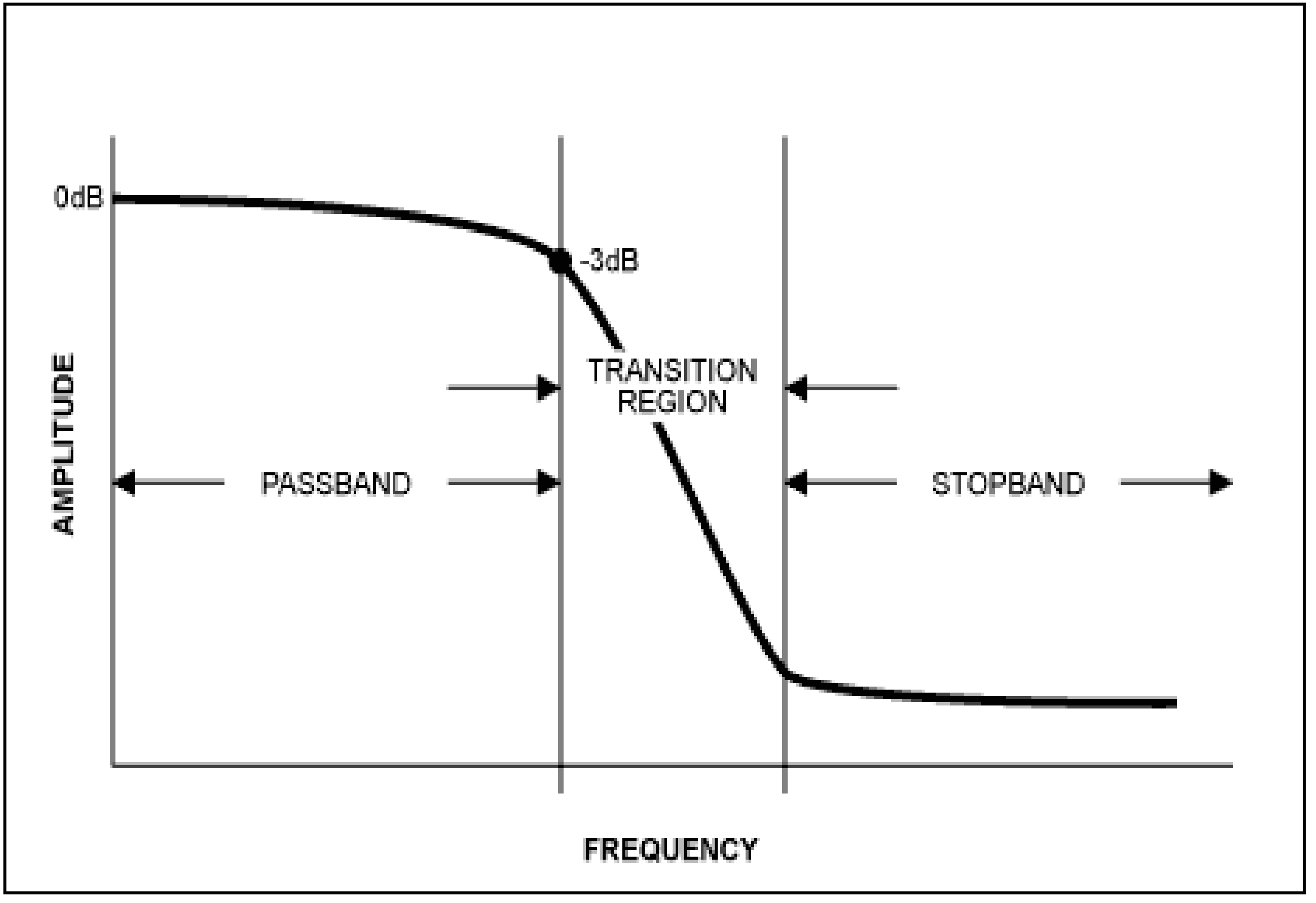


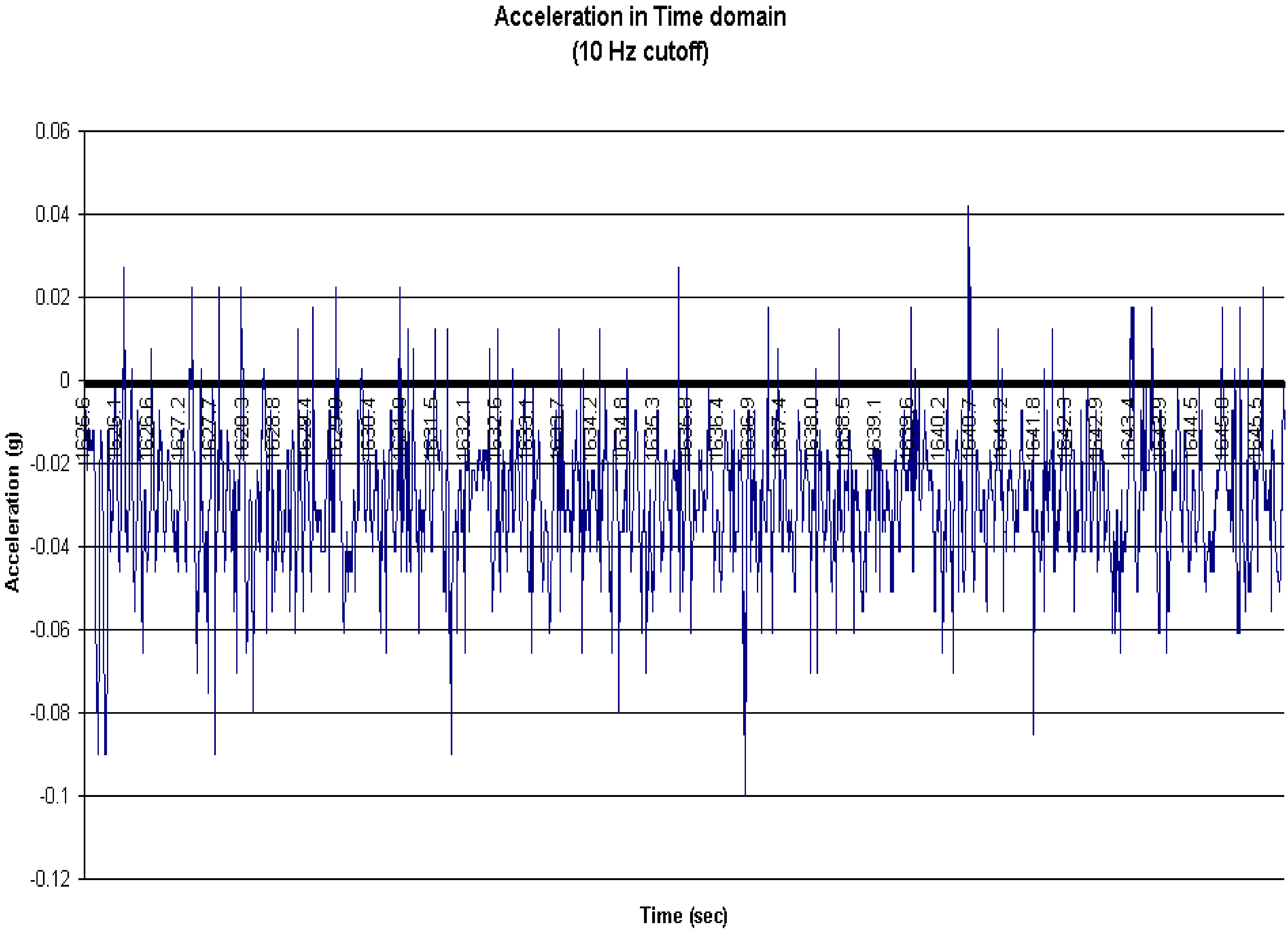
FFT of acceleration
(5 Hz cut off)
Acceleration (g)
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0.0 1.4 2.7 4.0 5.3 6.6 7.9 9.3 10.6 11.9 13.2 14.5 15.8 17.1 18.5 19.8 21.1 22.4 23.7 25.0 26.4 27.7 29.0 30.3 31.6 32.9 34.2 35.6 36.9 38.2 39.5 40.8 42.1 43.4 44.8 46.1 47.4 48.7
Frequency (Hz)

Filters

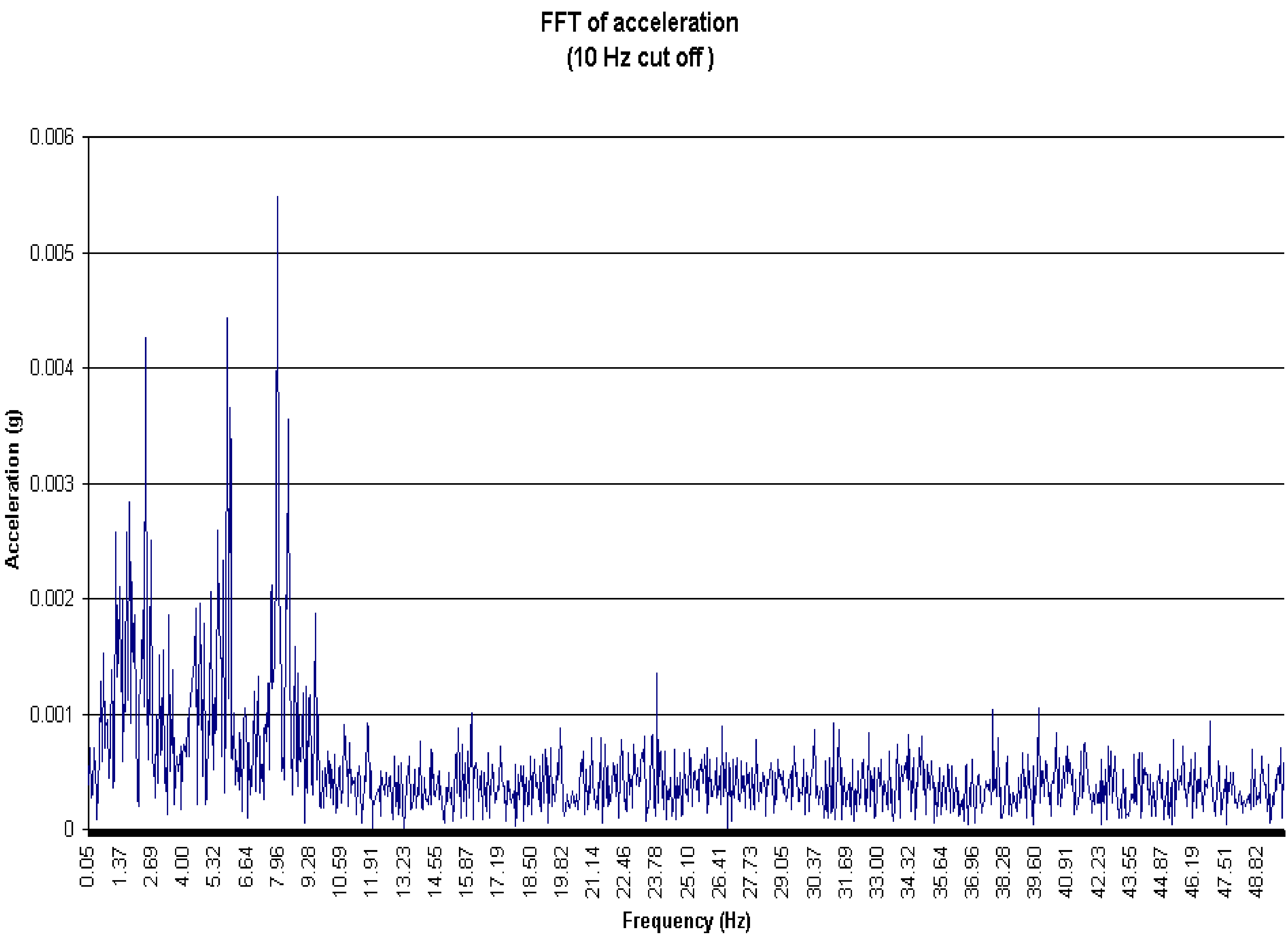
- Anti-aliasing to filter out frequencies above sampling rate
  - Before ADC conversion
    - Butterworth
    - Chebchev
    - Elliptical
- Higher order filters cause phase shift
- Important terms
    - dB= $20\log_{10}(A_1/A_0)$
    - Octave is geometric interval between f_0 and $2f_0$

Desired Low Pass Filter



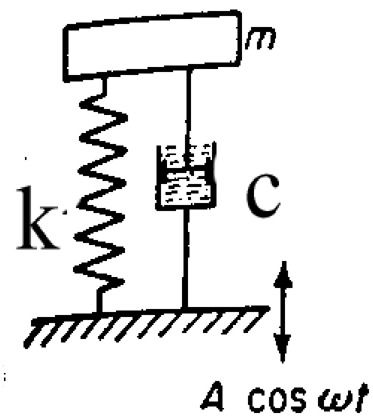


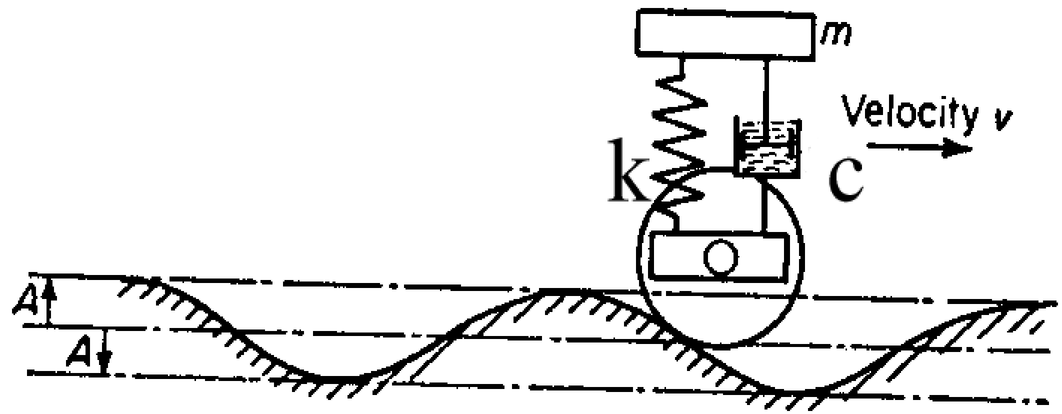
Acceleration in Time domain
(10 Hz cutoff)
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
Acceleration (g)
Time (sec)



FFT of acceleration
(10 Hz cut off)
Acceleration (g)
0.006
0.005
0.004
0.003
0.002
0.001
0
0.05
1.37
2.69
4.00
5.32
6.64
7.96
9.28
10.59
11.91
13.23
14.55
15.87
17.19
18.50
19.82
21.14
22.46
23.78
25.10
26.41
27.73
29.05
30.37
31.69
33.00
34.32
35.64
36.96
38.28
39.60
40.91
42.23
43.55
44.87
46.19
47.51
48.82
Frequency (Hz)

Rail Vehicle as Vibratory System





Simplified Model of Railway Suspension on Sinusoidal Rail
(as Single degree of Freedom)

Forced Damped Vibrations

- Steady state equation

  $m(d^2x/dt^2)+ c(dx/dt)+kx=F_o sinwt$

  or, $(d^2x/dt^2)+c/m(dx/dt)+k/mx=F_o/m\ sinwt$

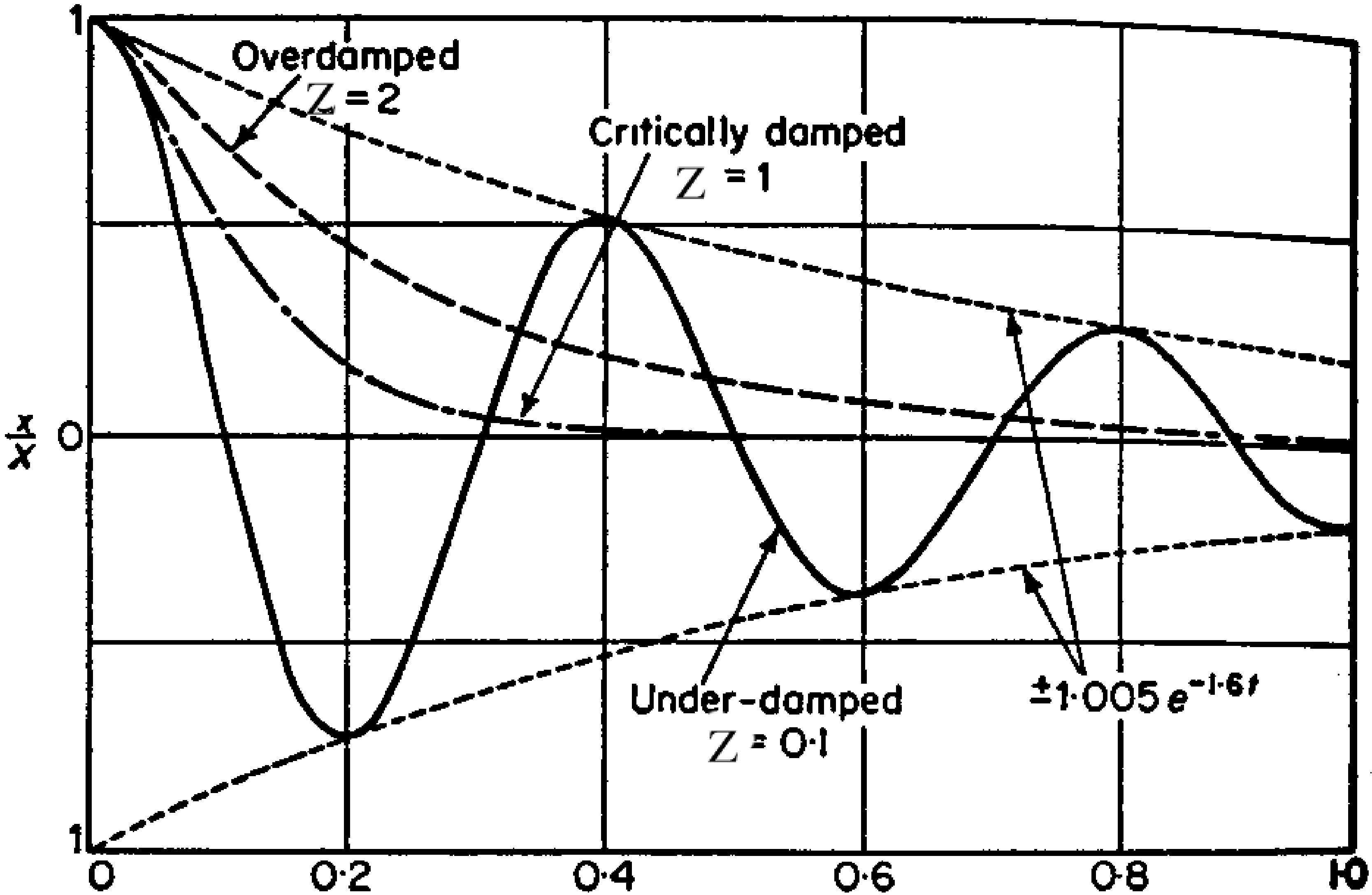
  or, $(d^2x/dt^2)+2w_n z(dx/dt)+w_n^2x=A\ sinwt$,

  where

  A=Amplitude of forcing function = F_o/m ,

  w_n=natural angular frequency =$[k/m]^{0.5}$ &

  Z=damping factor= $c/c_{critical}$



Effect of damping factor on Transient Response to Impulse

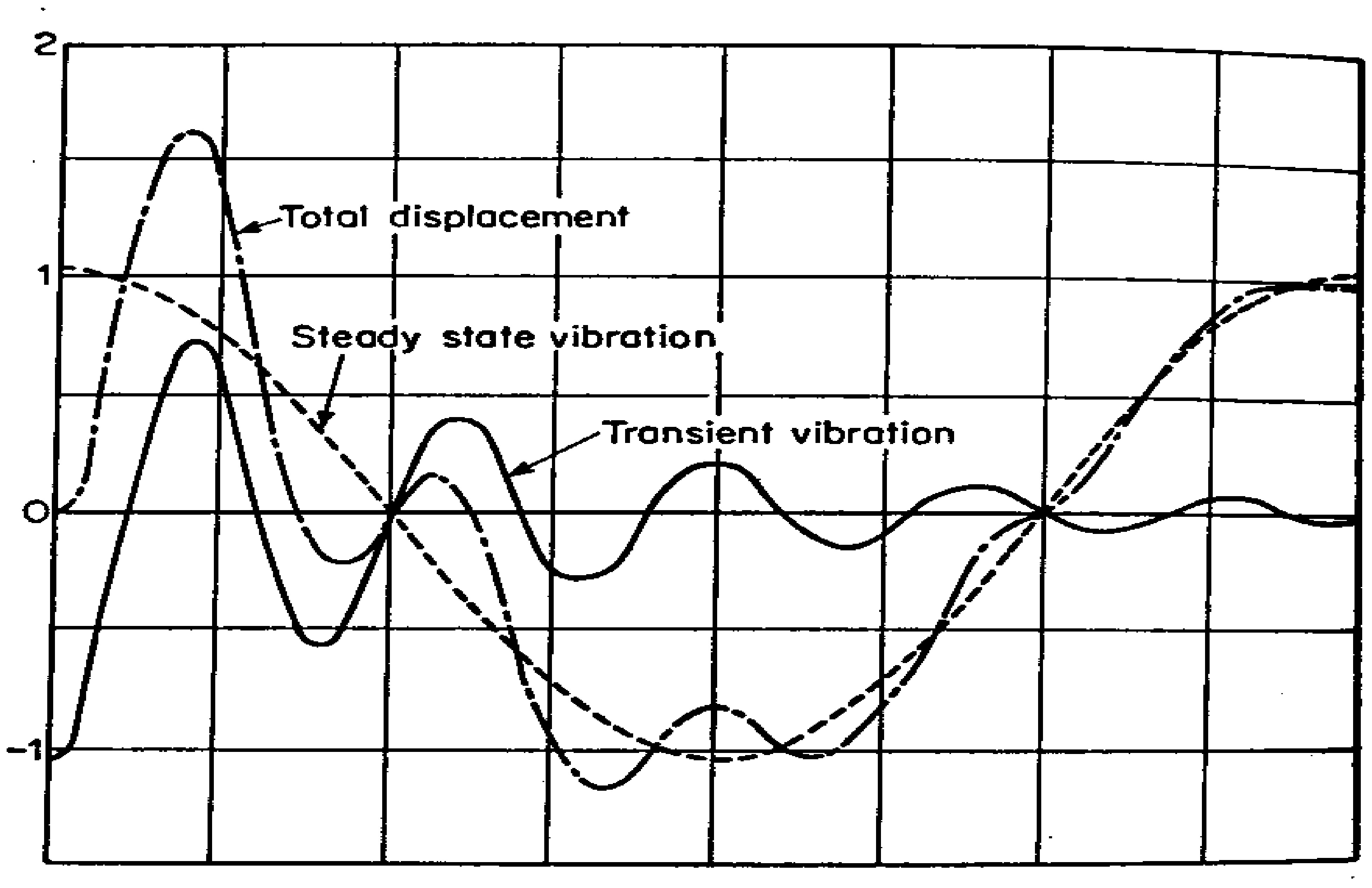
Solution for Forced Damped Vibrations

- X(t)=Steady state response +transient response
- Steady state response
  - $X_S * \sin(wt-ø)$,where

    $X_S = A * 1/[\{1-(w/w_n)^2\}^2+\{2Zw/wn\}^2]^{0.5}$ &

    $\tan ø = 2Z(w/w_n)/[1-(w/w_n)^2]$
- Transient response
  - $X_0 e^{-Zwt} \sin[(1-z^2)^{0.5} w_n t + ø_0]$, where

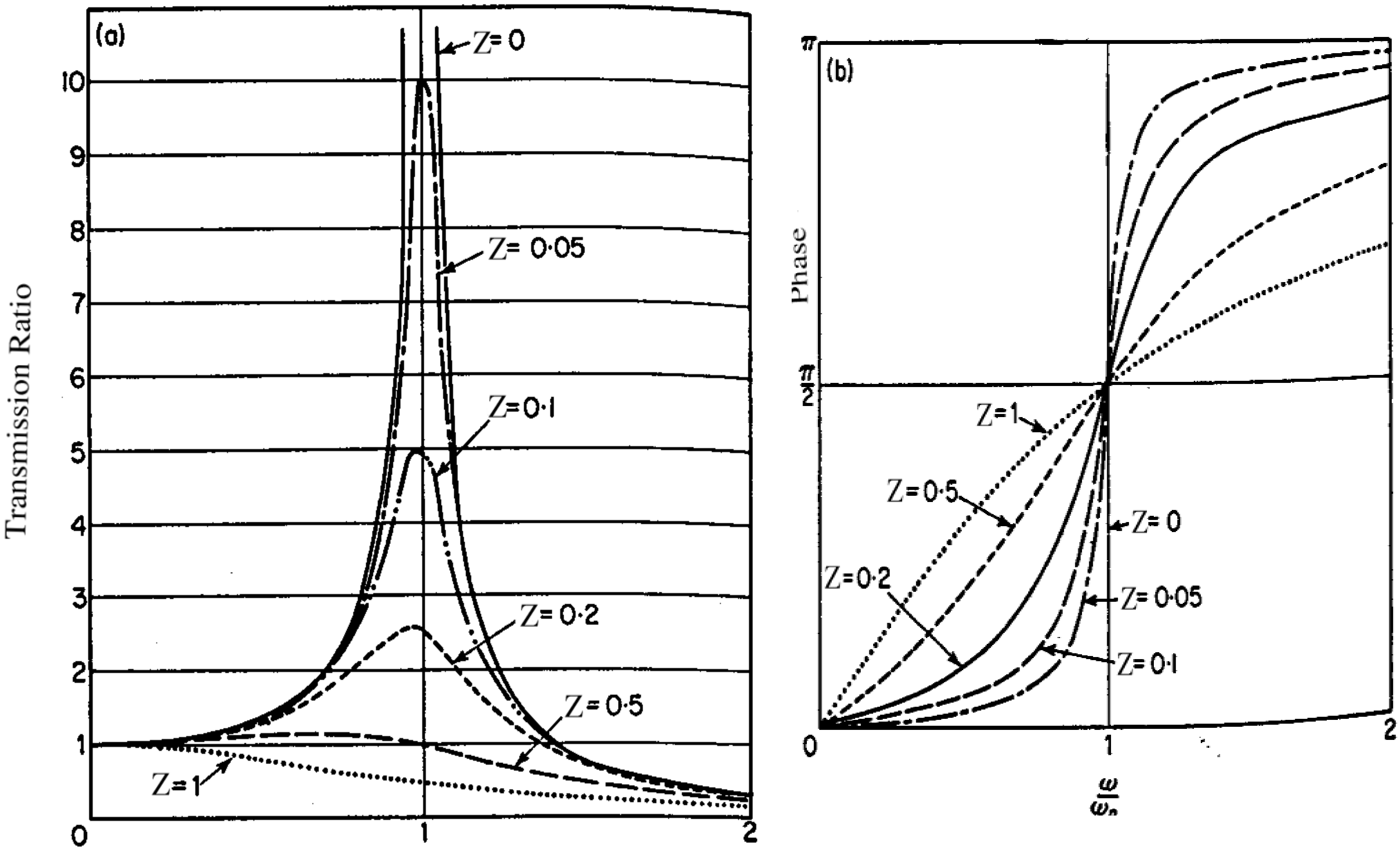
    $ø_0$, X_0 depend on initial conditions



Steady State & Transient Response of the System

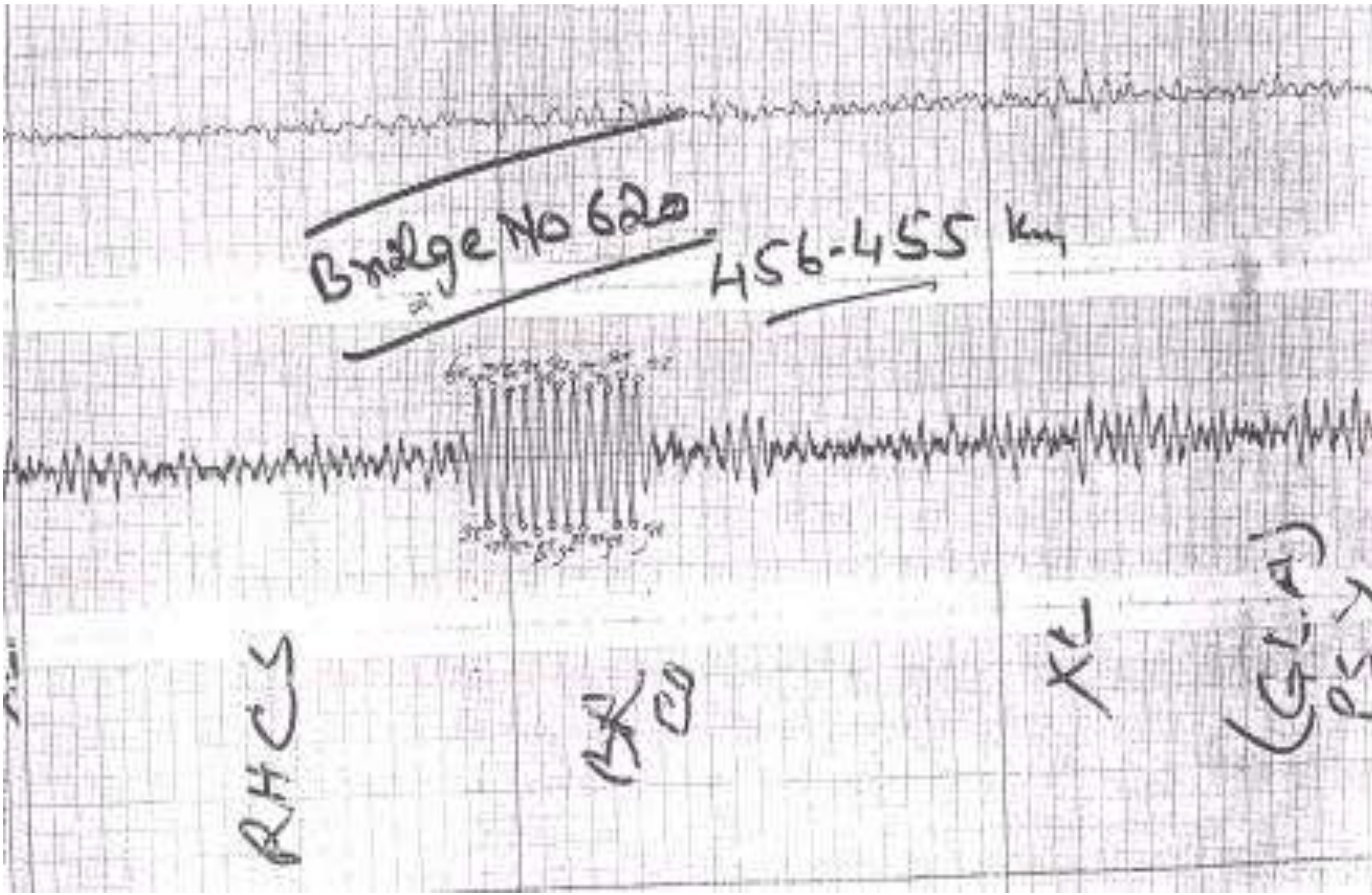
Some Terms Used

- Natural Angular Frequency = w_n
- Damped natural angular frequency $w_d = w_n * \sqrt{[1-Z^2]}$
- Damping factor = Z
  - normally preferred value, 0.2 to 0.3
- Transmission ratio = X_S / A
- Resonance $w = w_n$



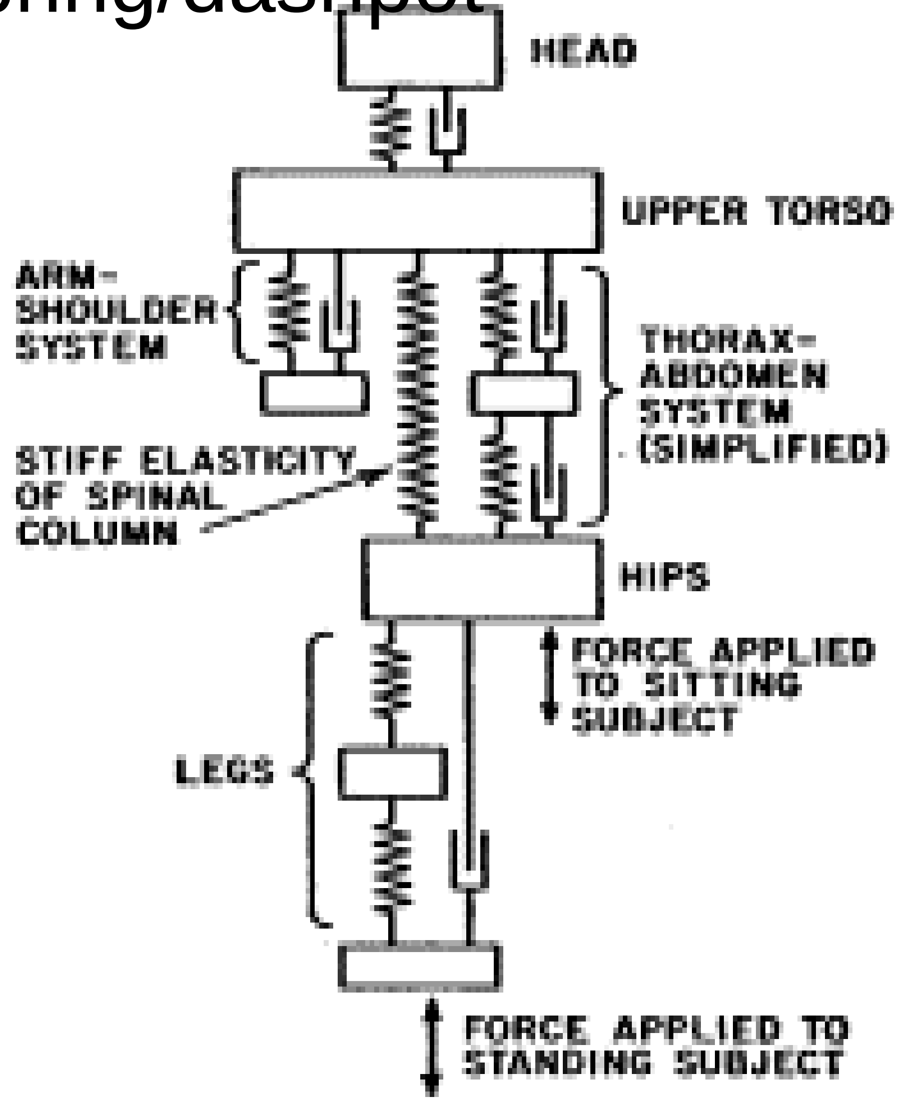
Effect of damping factor on steady State Response near resonance conditions

Resonance



Effect of Vibration on Human Body

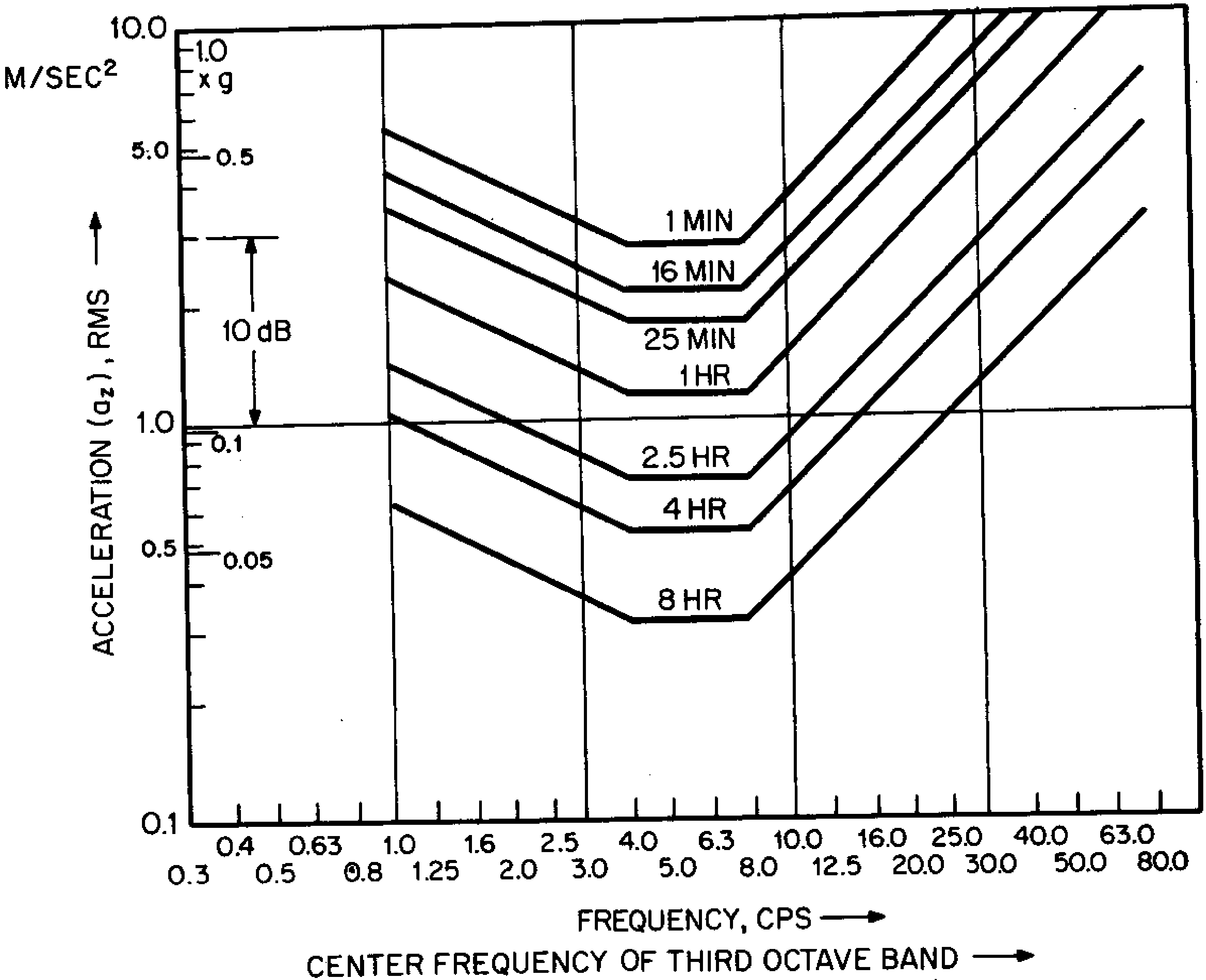
Model of Human body as lumped masses connected with spring/dashpot



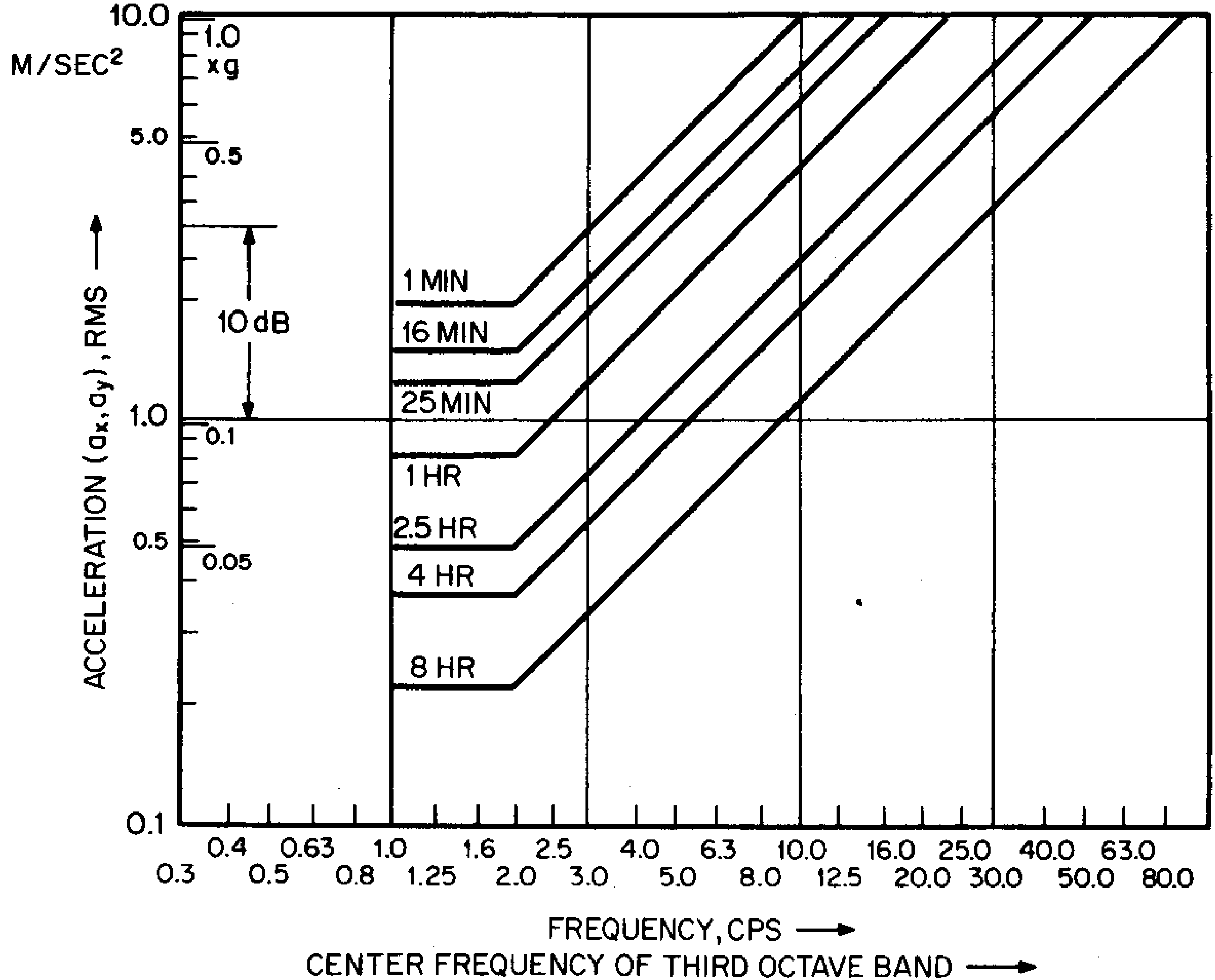
Effect of Vibration on Human Body

- Impulse/Shock in collisions
- Short term exposure
  - Unpleasant Sensation
  - Can withstand higher amplitudes
- Long duration exposure
  - Leads to fatigue after some time
- Function of Frequency, amplitude and posture

Effect of Prolonged Exposure to Vibrations on Humans

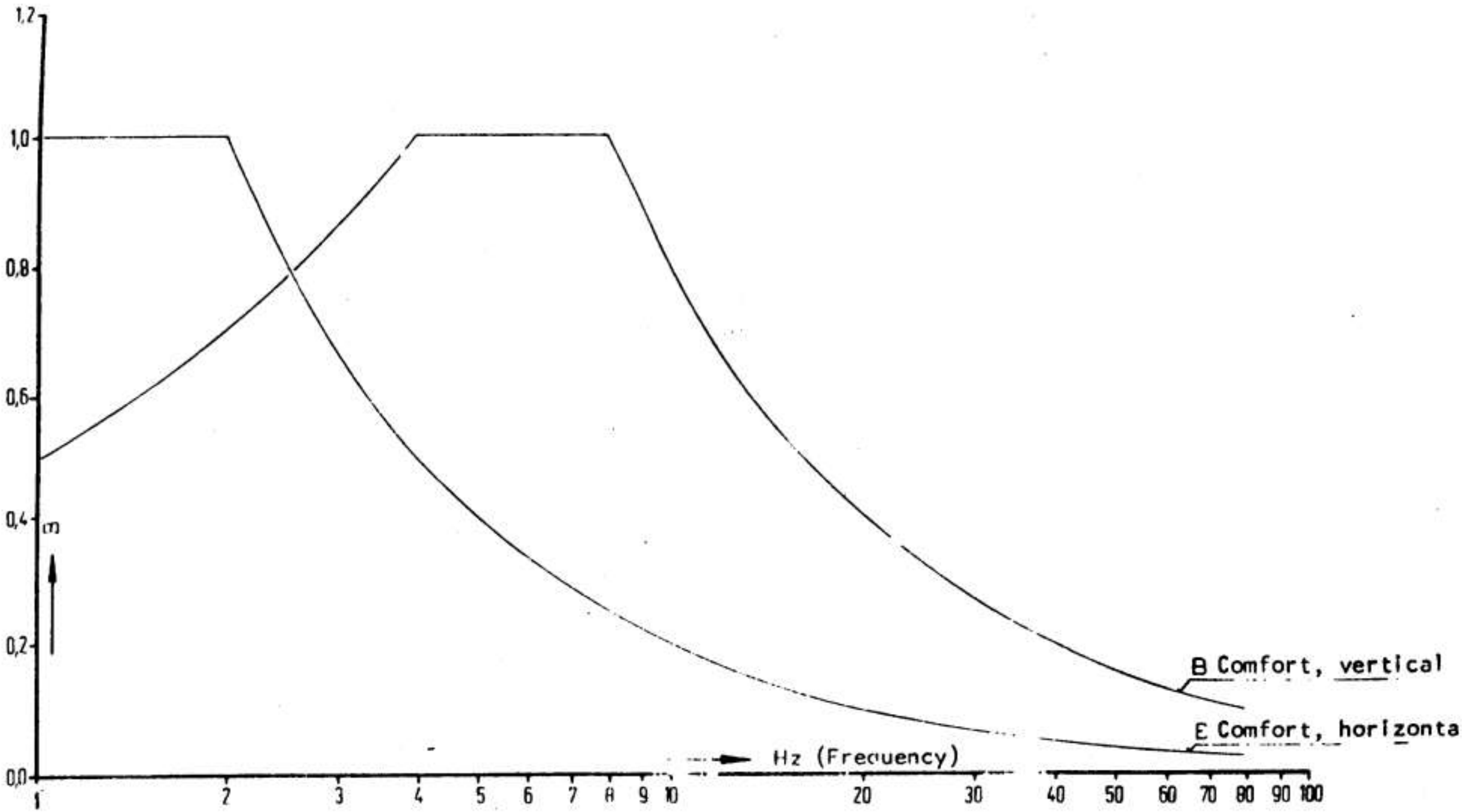


10.0
M/SEC²
1.0
x g
5.0
0.5
1.0
0.1
0.5
0.05
0.1
10 dB
ACCELERATION (a_z), RMS
1 MIN
16 MIN
25 MIN
1 HR
2.5 HR
4 HR
8 HR
0.4 0.63 1.0 1.6 2.5 4.0 6.3 10.0 16.0 25.0 40.0 63.0
0.3 0.5 0.8 1.25 2.0 3.0 5.0 8.0 12.5 20.0 30.0 50.0 80.0
FREQUENCY, CPS
CENTER FREQUENCY OF THIRD OCTAVE BAND



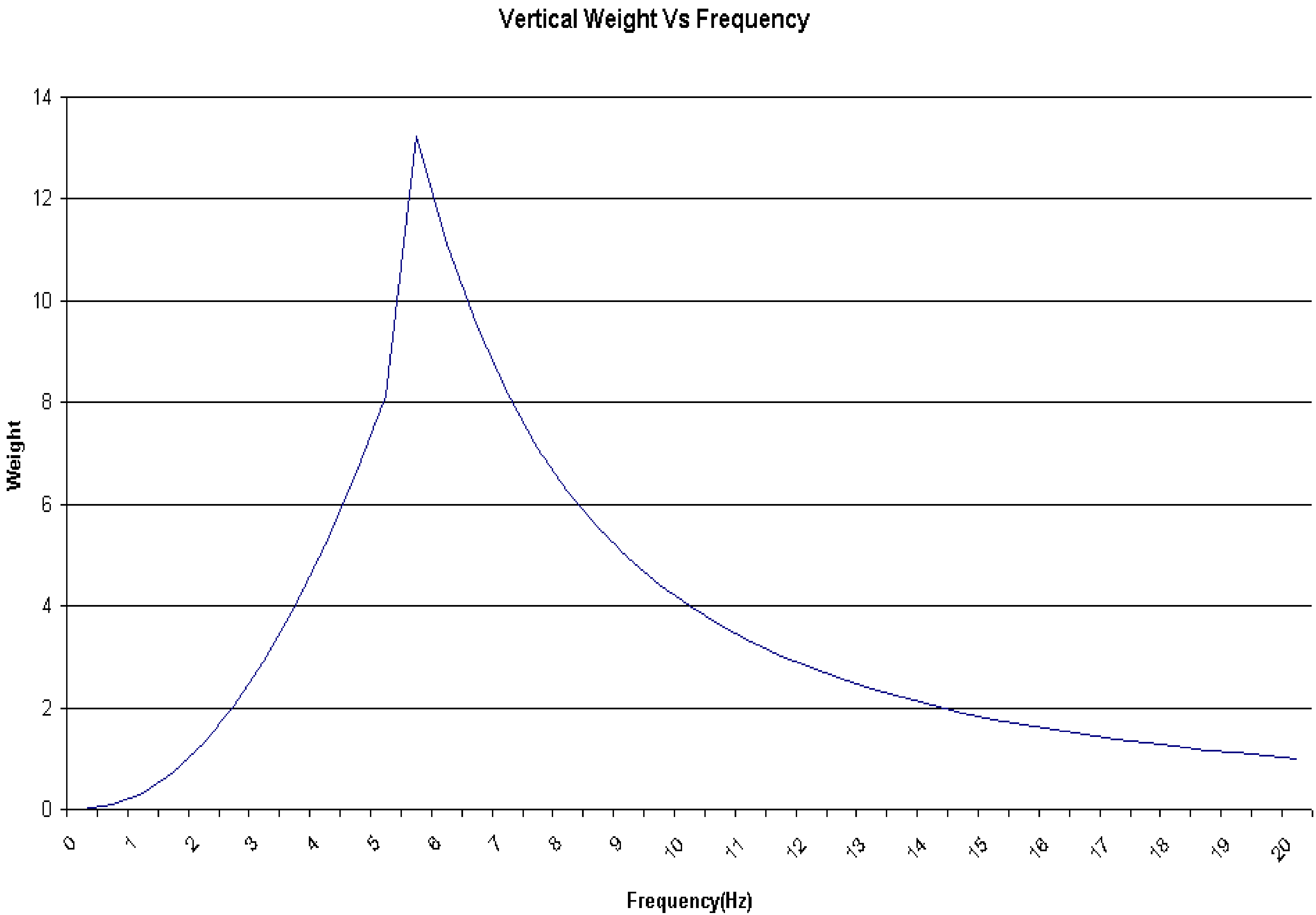
M/SEC²
1.0 xg
10.0
5.0
0.5
1.0
0.1
0.5
0.05
0.1
10 dB
ACCELERATION (a_x, a_y), RMS
1 MIN
16 MIN
25 MIN
1 HR
2.5 HR
4 HR
8 HR
0.4 0.63 1.0 1.6 2.5 4.0 6.3 10.0 16.0 25.0 40.0 63.0
0.3 0.5 0.8 1.25 2.0 3.0 5.0 8.0 12.5 20.0 30.0 50.0 80.0
FREQUENCY, CPS
CENTER FREQUENCY OF THIRD OCTAVE BAND

Frequency Dependant Weights as per ISO 2631(1974)

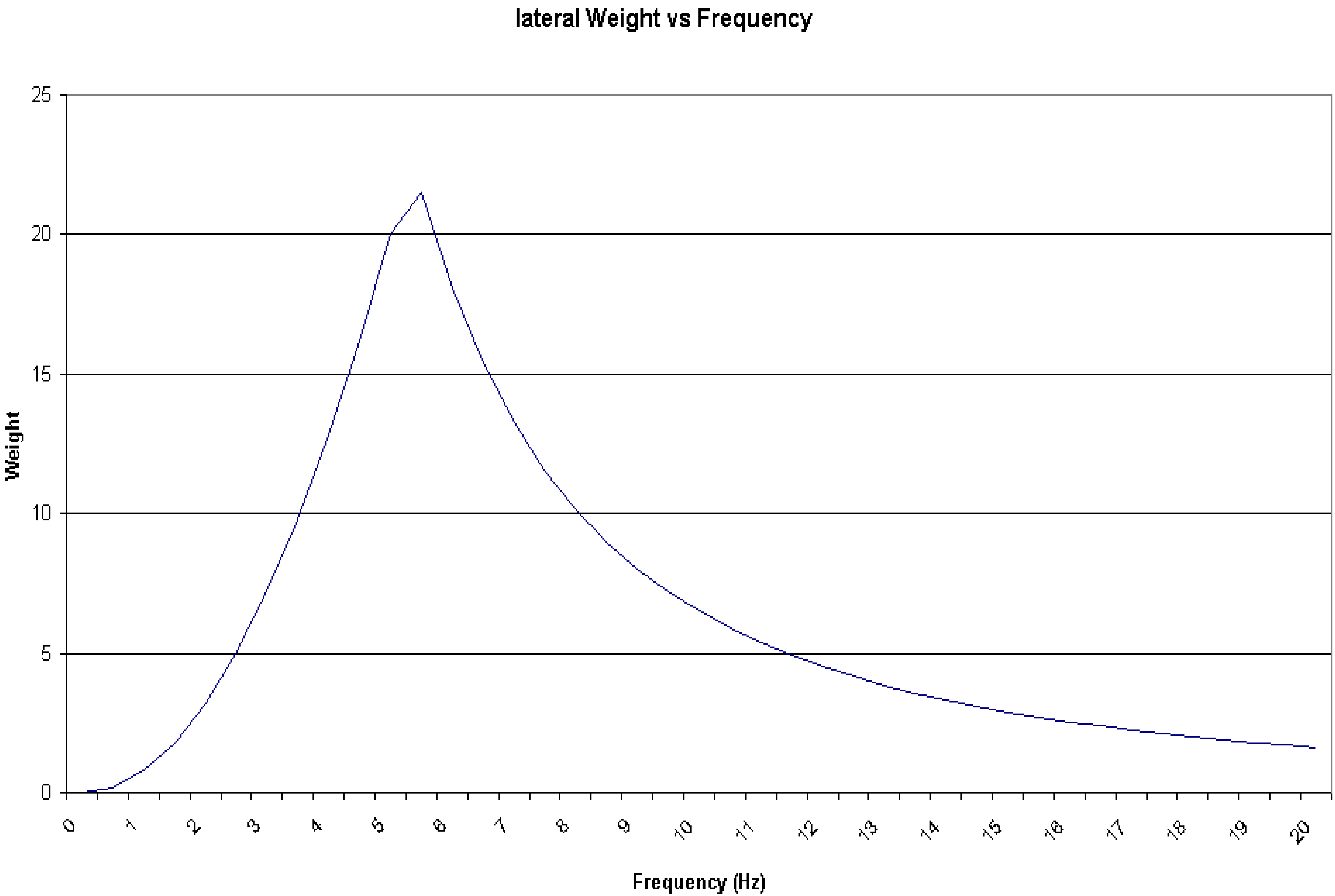


Sperling's Ride Index

- Human sensation of comfort proportional to
  - Displacement (sinusoidal)
  - Acceleration
  - Rate of change of acceleration
- $RI=.896(g(f)*b^3/f)^{0.1}$, b= acceleration amp
- Ride comfort correction factor $g(f) = kf^2$
  - k=.325 for vertical RI (0.5-5.4Hz)
  - k= .8 for lateral RI (0.5-5.4 Hz)
  - k=1 for goods stock



Vertical Weight Vs Frequency
Weight
0
2
4
6
8
10
12
14
Frequency(Hz)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20



lateral Weight vs Frequency
Weight
Frequency (Hz)
0
5
10
15
20
25
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Track and Related Issues

Indian Railway Track

- Classified into two categories
- Main Line (speed <110 km/h)
- High Speed
  - For speed upto 150 Kmph
  - Based on Vol-I of Civil and Mechanical Engg Report No-I (C&M-I) dated May 1969 for "Increase of Speed on DLI-HWH Route Feasibility Study"

Track Recording Cars

- Recording speed 50 -100kmph
- Recording every .4m
- Self adjusting offset after some time
- Recording periodicity
  - Depends on track category

Derailment

- Wheel climbing rail
  - Tight gauge
  - Due to excessive angle of attack
    - Sharp flange/Sharp curve -too much versine
  - Excessive lateral force- Nadal's formula
    - Hy/Q =(tanA-mu)/(1+mu tanA)= .997,

    where, A = flange angle wrt to horizontal ; mu=.27
    - Friction assists **only** if angle of attack causes rail wheel rubbing to be advanced

Derailment

- Wheel offloaded due to
  - Excessive spring deflection
    - Due to inadequate ballast
    - Unevenness of track
    - Poor quality ballast -caked up
  - **Resonance**
    - Poor damping
    - On multi-span bridges (more likely on steel girder type)

Derailment

- Rail fractures due to
  - Inadequate stress relieving
  - Improper UFD
  - Inadequate ballast
  - Wheel flats?
- Shifting of sleepers
  - Prud Homme's Limit (wooden sleeper)
    - $Hy_{2m} < .85(1+P/3)$,
  - Wrong shape of ballast packing

Oscillation trials of Rolling Stock


वटवा
18791R
14 14:02

3rd Report of Standing Criteria Committee dated January 2000

- To evolve criteria for assessment of stability of rolling stock on IR
- Composition
  - ED s RDSO
- Formulate
  - Oscillation trial procedure
  - Evaluation criteria

Test Track

- Straight 1 Km X 2
  - Station yard
  - 700-800 m Curve of about 2 degree
- Rundown track worse than 90% of IR track
- On main line track
  - Include high speed (C&M I vol I) for speed >110kmph
- Long confirmatory run for 10-50kms with resonance check on hard spots like L-Xing, Culverts, Bridges

Procedure

- Test Speed (Loaded & Empty)
  - Start with low speed (60kmph/80kmph)
  - Increase speed in increments of 5/10Kmph
    - Stop if any limit is exceeded
  - Max speed 10% higher than the proposed speed
- Test vehicle to be last vehicle (except loco)
- Free end bogie (leading bogie for loco) usually instrumented
- Data acquisition system usually in oscillograph car


G CAPACITY
TONNES
BEML TREASURY VAN
OSCILLATION TRIALS
BY
RDSO TESTING Dte
OT-III UNIT


1. 11. 2002

RIDE INDEX CALCULATION

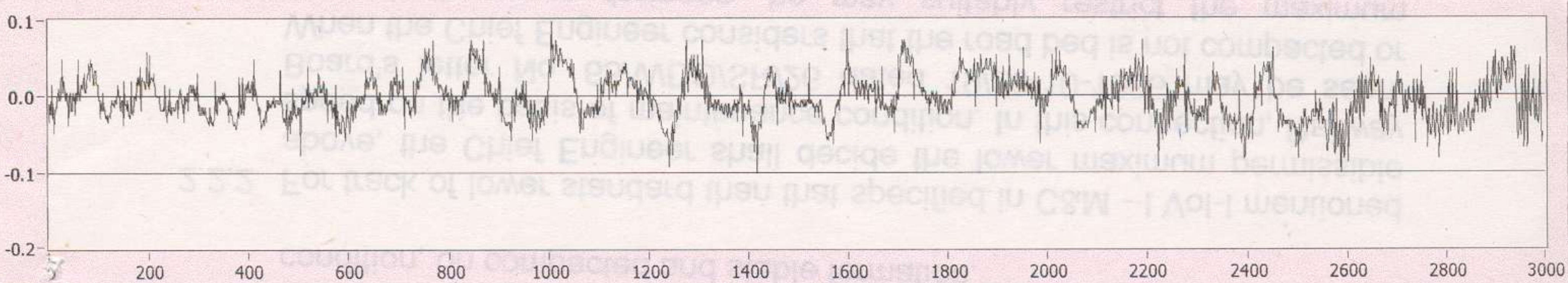
Calculation for samples from 18553 to 21549

Channel	DC Offset	Conversion Factor	Scan	Type of Vehicle	Mode
3	0.0000	1.0000	100	Loco/Carriage	Lateral

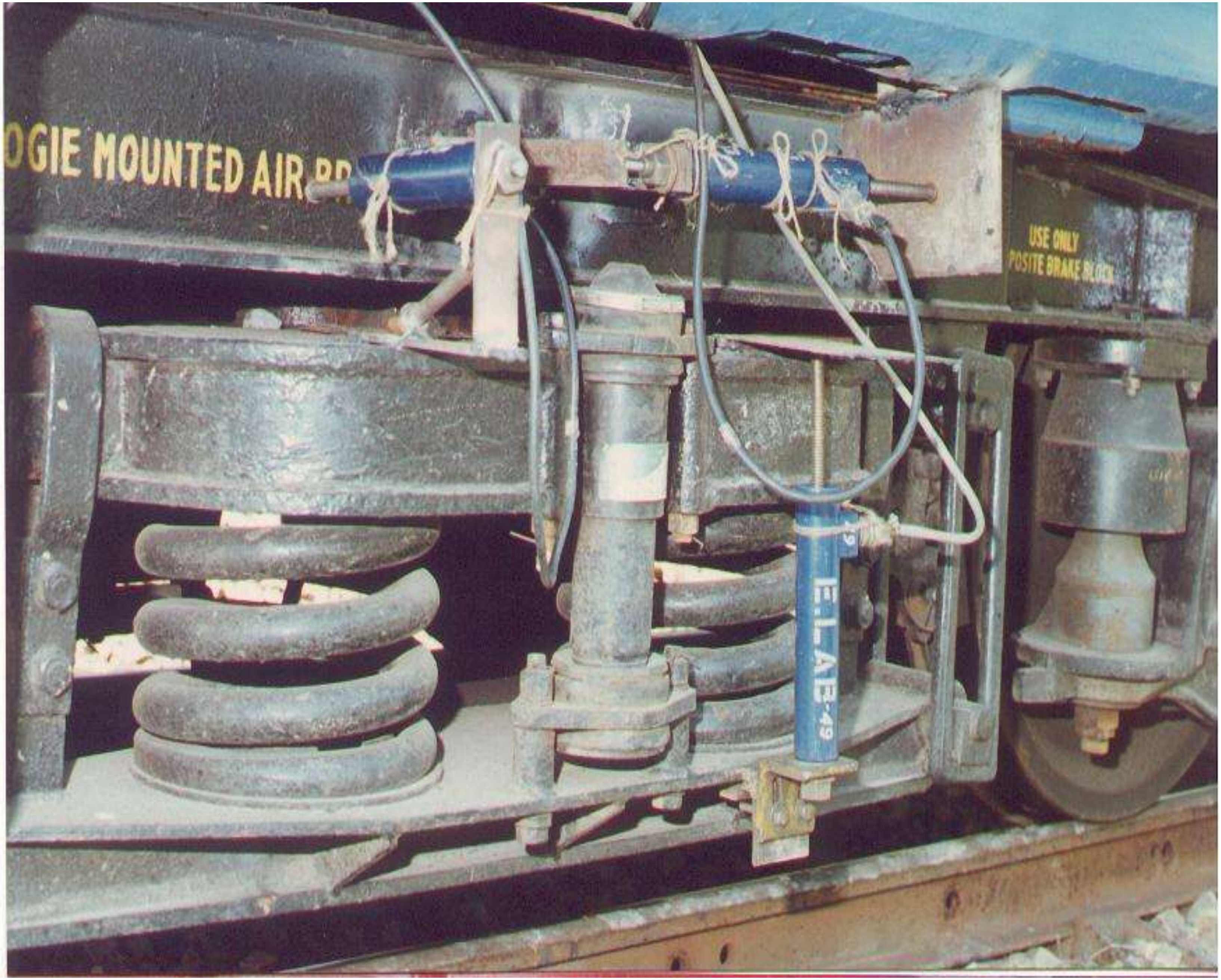
Mean Acceleration	0.022
Standard Deviation	0.017
RMS Acceleration	0.028
Percentile Max. 99.85/0.15	0.093
Max. Acceleration	0.102
Average Ride Index	2.729

UIC Percentile Values

99.85%	50.00%	0.15%
0.073	-0.005	-0.093



BACK


OGIE MOUNTED AIR BR
USE ONLY
POSITE BRAKE BLOCK
E.LAB-49


40
29. 10. 2002


1. 11. 2002

Criteria for Carriage

- Ride index <3.5,
  - preferred 3.25
  - upto 4 for EMU/DMU
- <.3g accelerations in vertical & lateral directions
- Isolated peak upto .35g if no resonance

Criteria for wagons

- Hy_{2m}<.85(1+P/3),P= axle load (Prud Homme's limit)
- Hy/Q (for >1/20 sec) <1
- In case Hy cannot be measured,
  - Ride index < 4.5, preferred 4.25
- General stable running characteristics based on
  - Accelerations
  - Spring deflections

Other Tests Related to Coaches

- Squeeze test
  - Check buffing /pay loads
  - Measure deflections, stresses and permanent sets
- Crash worthy tests
  - Withstand impact at 60 km/h
  - In passenger area
  - Actual crashes carried out

Example of Squeeze Test

- BG BEML shell (model 816)
- Requirements
  - Max stress 90% of lower YP
  - No permanent set at 102 mT load
  - Max shell deflection (lateral & vertical)
    - 10 mm at centre
    - 6 mm at ends
  - No weld failure

Test Fixtures

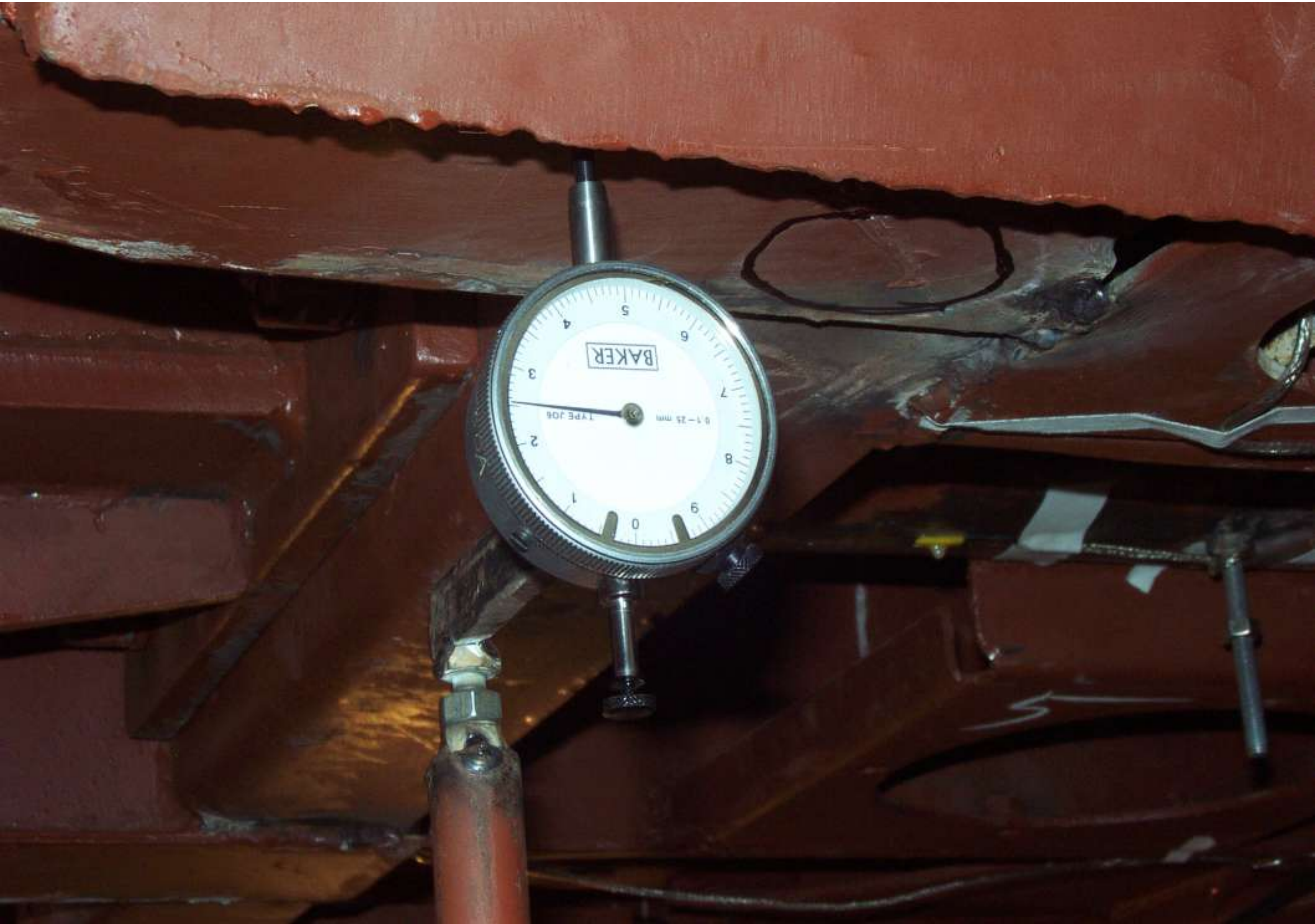

SQUEEZE TEST
OF 816 MODEL
RDSO
TESTING D'TE


NMP
94
91

Loading Devices

Deflection Measurement


109
119


BAKER
TYPE J06
0.1 – 25 mm

Stress Measurement

Crash Test


R D S O

Thank You!!!