Progress on FE modelling for Newtonian noise estimates

David Rabeling

Mark Beker, Eric Hennes, and
Jo van den Brand

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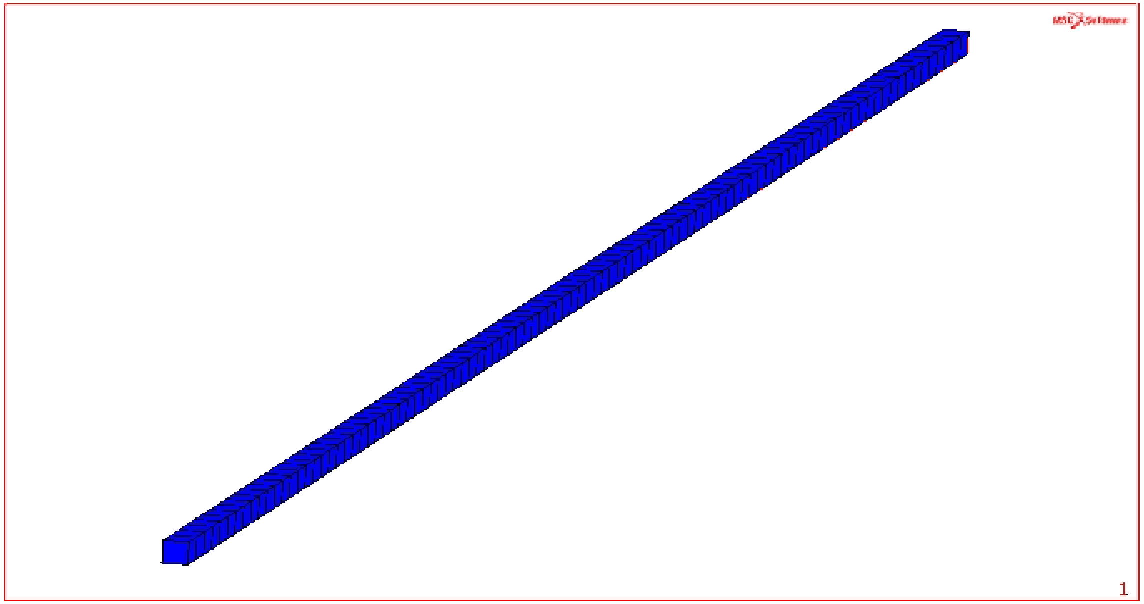
First and second generation detectors:

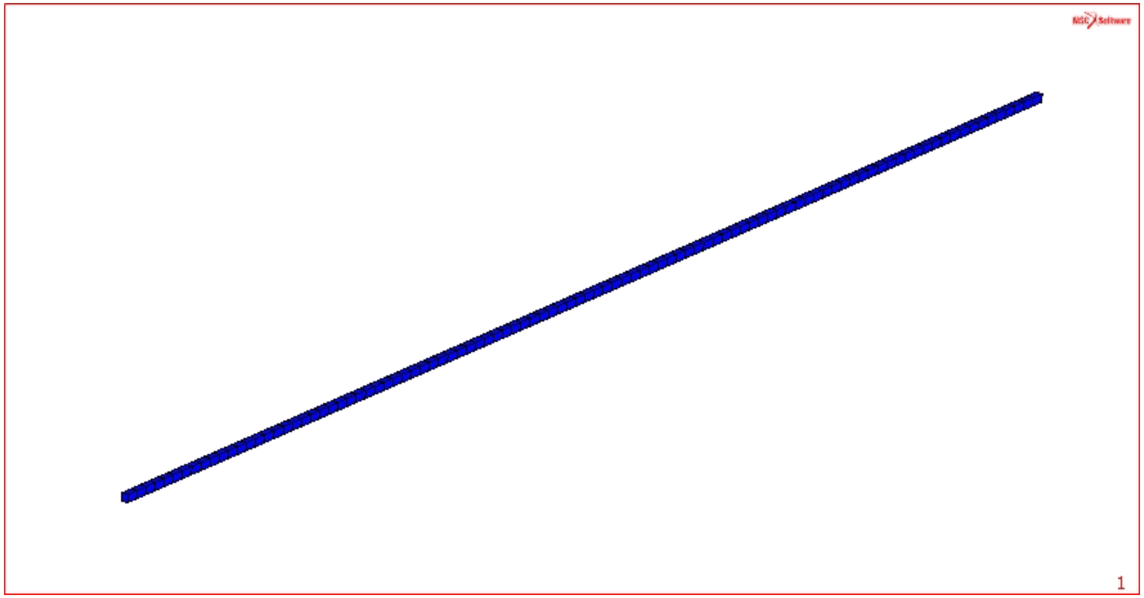
- Saulson made first predictions and set upper limits to the expected GG noise levels in first generation detectors.
- Beccaria *et. al.* created a more accurate estimate of GG noise for VIRGO.
- Thorne and Hughes published a full analytic analysis of GG noise and human interaction with the detector.

Third generation detectors:

- Cella presented various studies on subterranean gravitational wave detectors and accompanying noise reduction due to placing the detector test masses at various depths and in different types of cavities.

We are now working on a FE model to verify more complex cavity models and soil compositions.





- We want to probe the Newtonian noise at a height H from a source of pressure or shear waves and compare that to our analytic model

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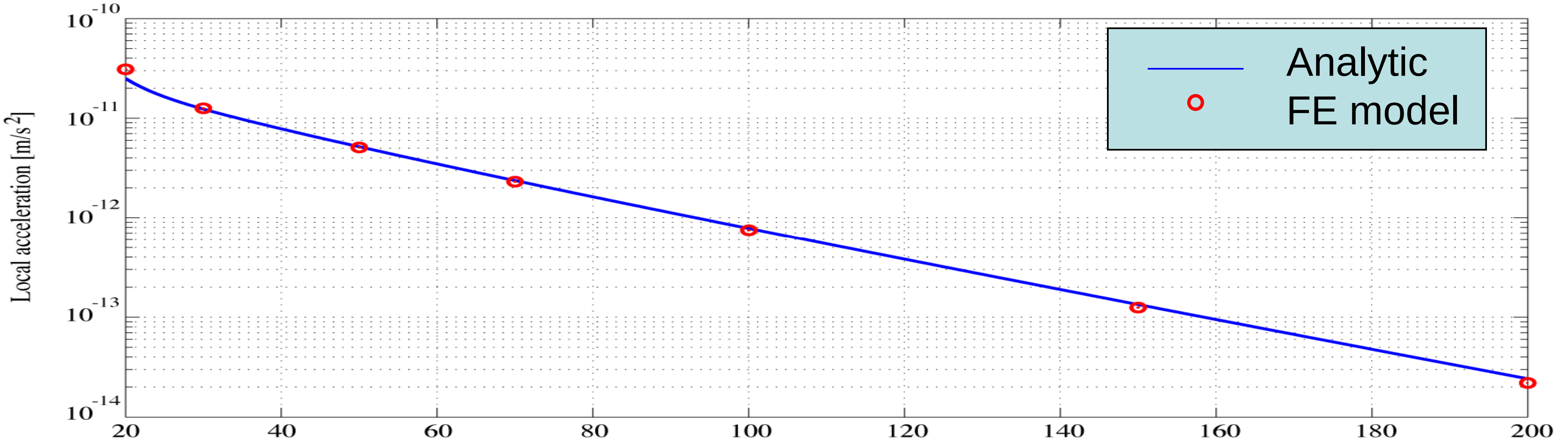

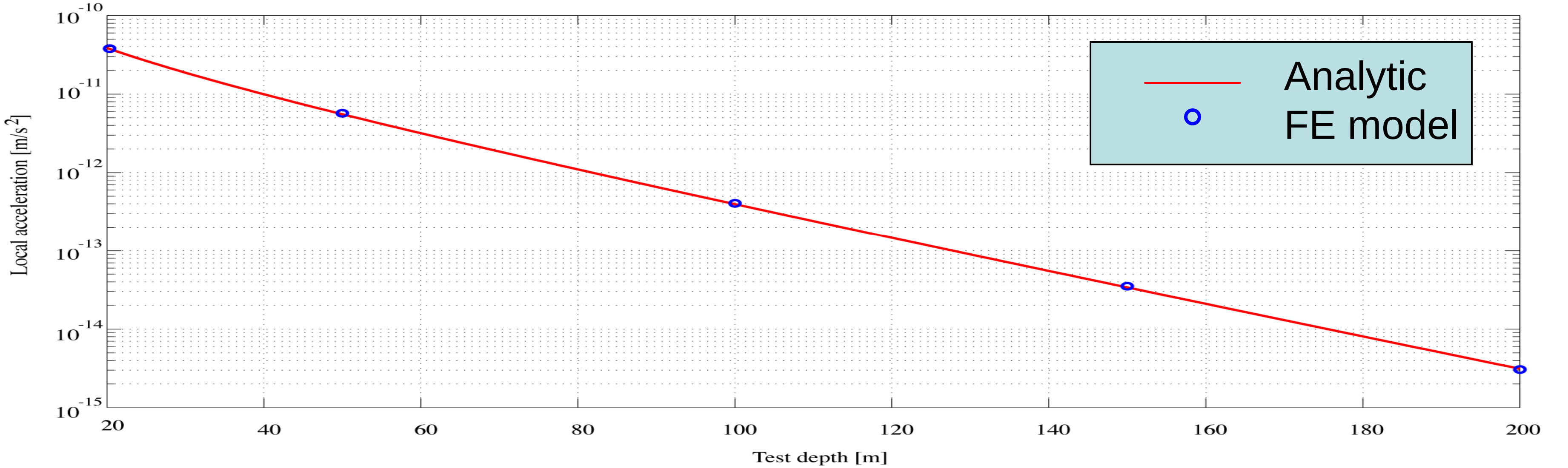

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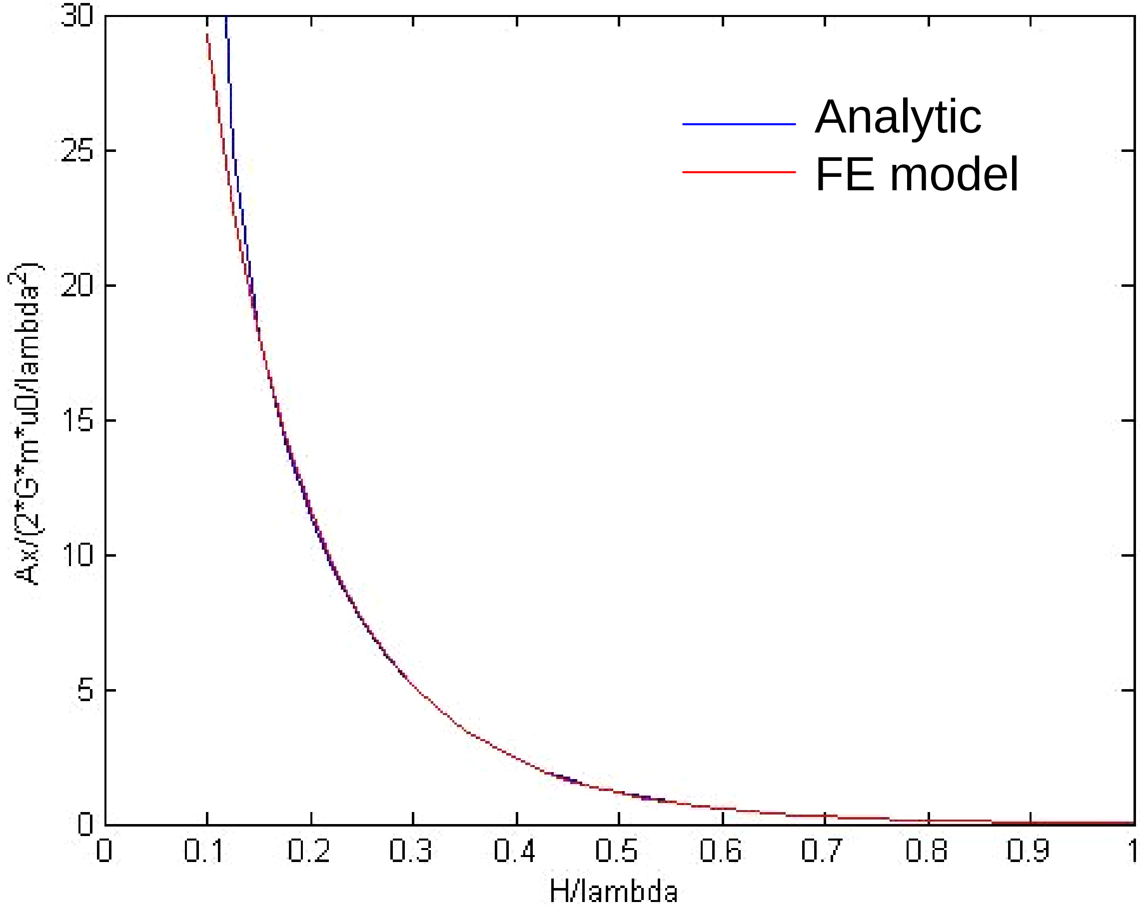
SEVENTH FRAMEWORK PROGRAMME

Converting this to dimensionless parameters



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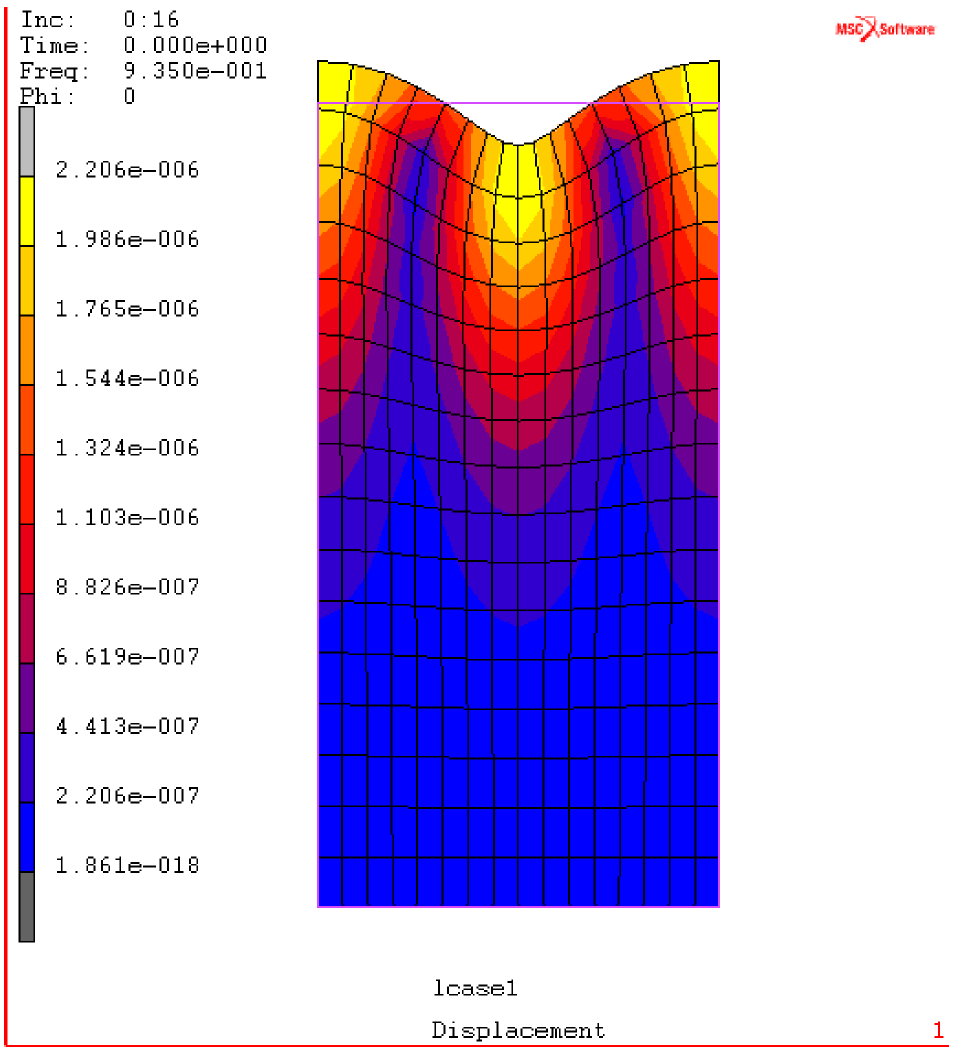
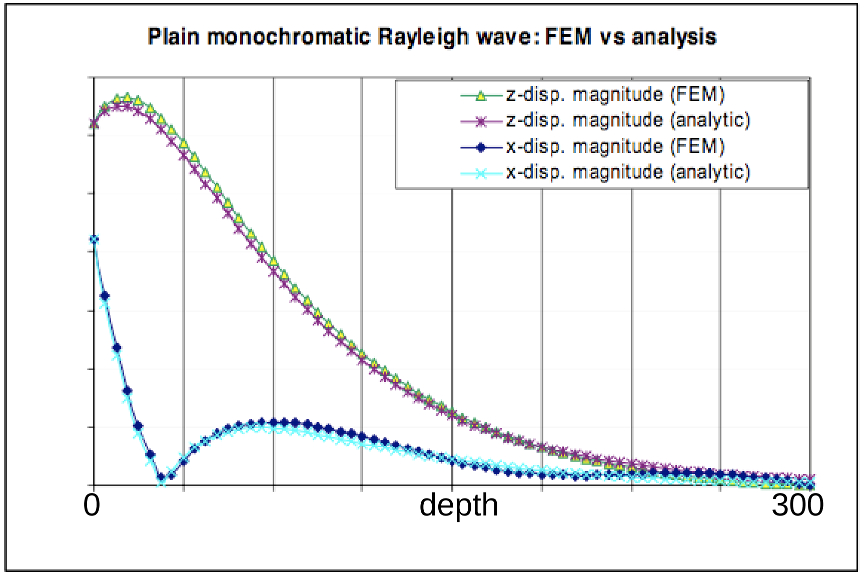
Harmonic Rayleigh wave: λ=123m,

$$c = 0.61\sqrt{E/\rho}$$



Model parameters:

- ρ = 2000kg/m^3
- E = 80MPa
- $\nu = 0$
- f =1Hz



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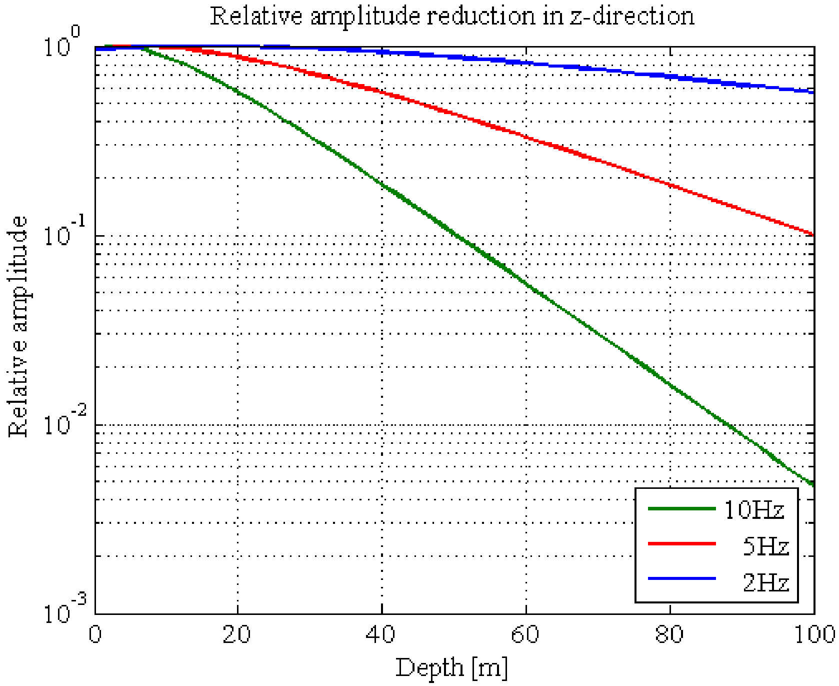
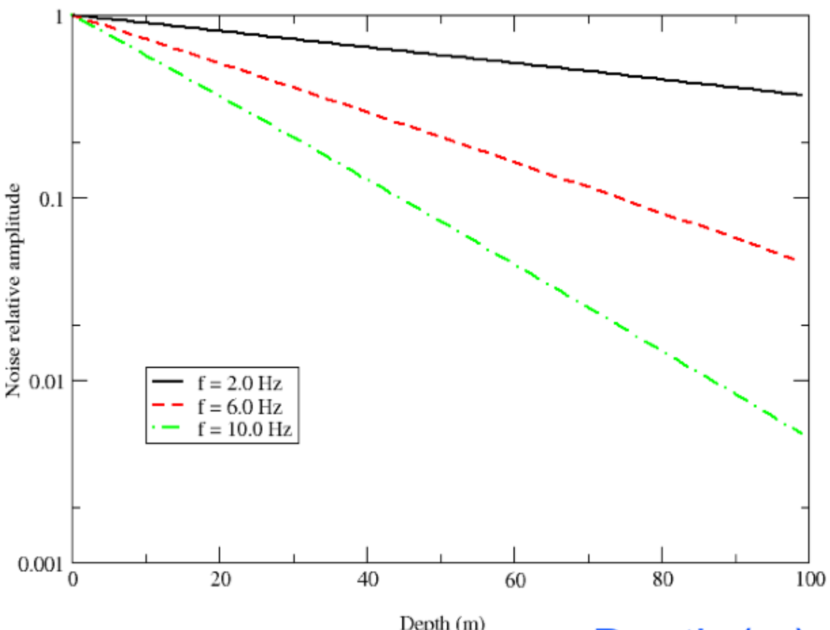
SEVENTH FRAMEWORK PROGRAMME



← Rayleigh wave: λ=400m,

Seismic suppression due to depth (Cella)



Rayleigh wave: λ approx 400 →

Depth (m)

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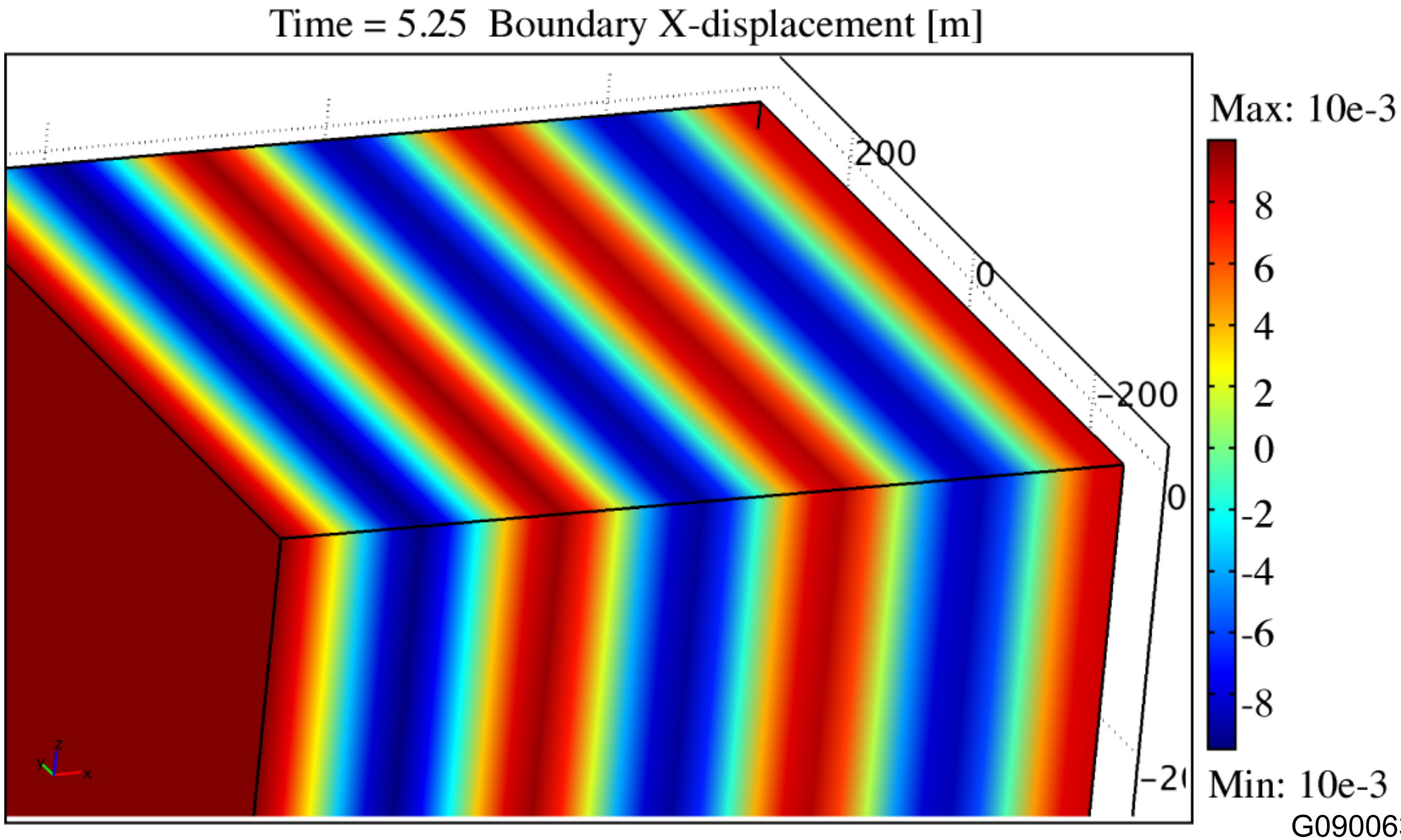
Verify analytic calculation of the NN due to a continuous pressure wave through a homogeneous half space.



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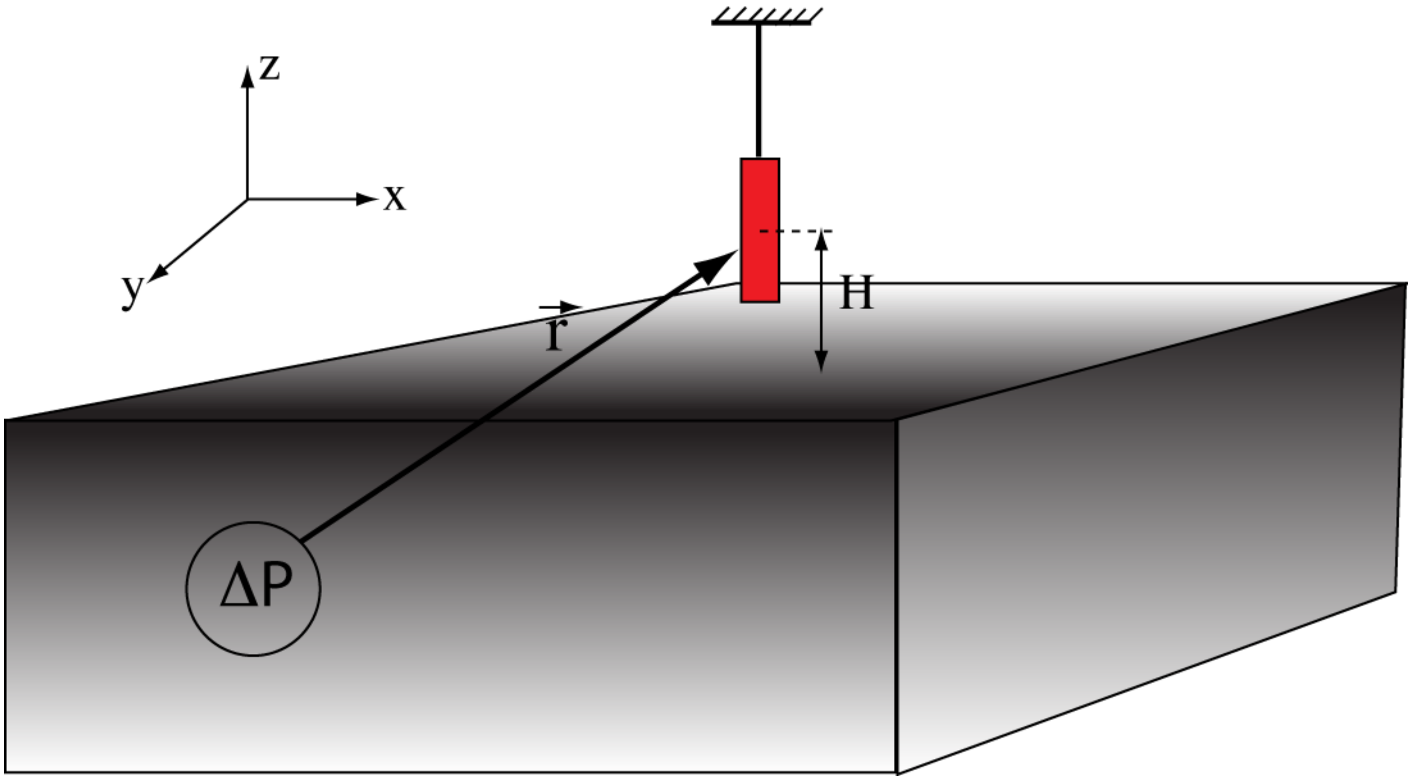

Pressure wave through a homogeneous half space in the positive x-direction:

$$a_x = 2\pi G \rho u_0 e^{-2\pi(\mathcal{H}/\lambda)}$$

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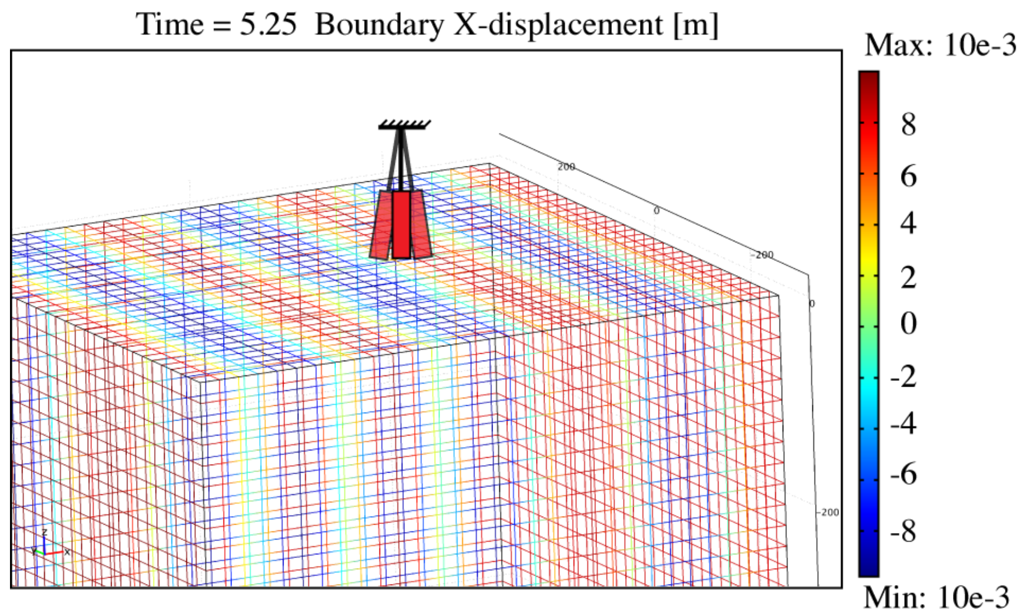
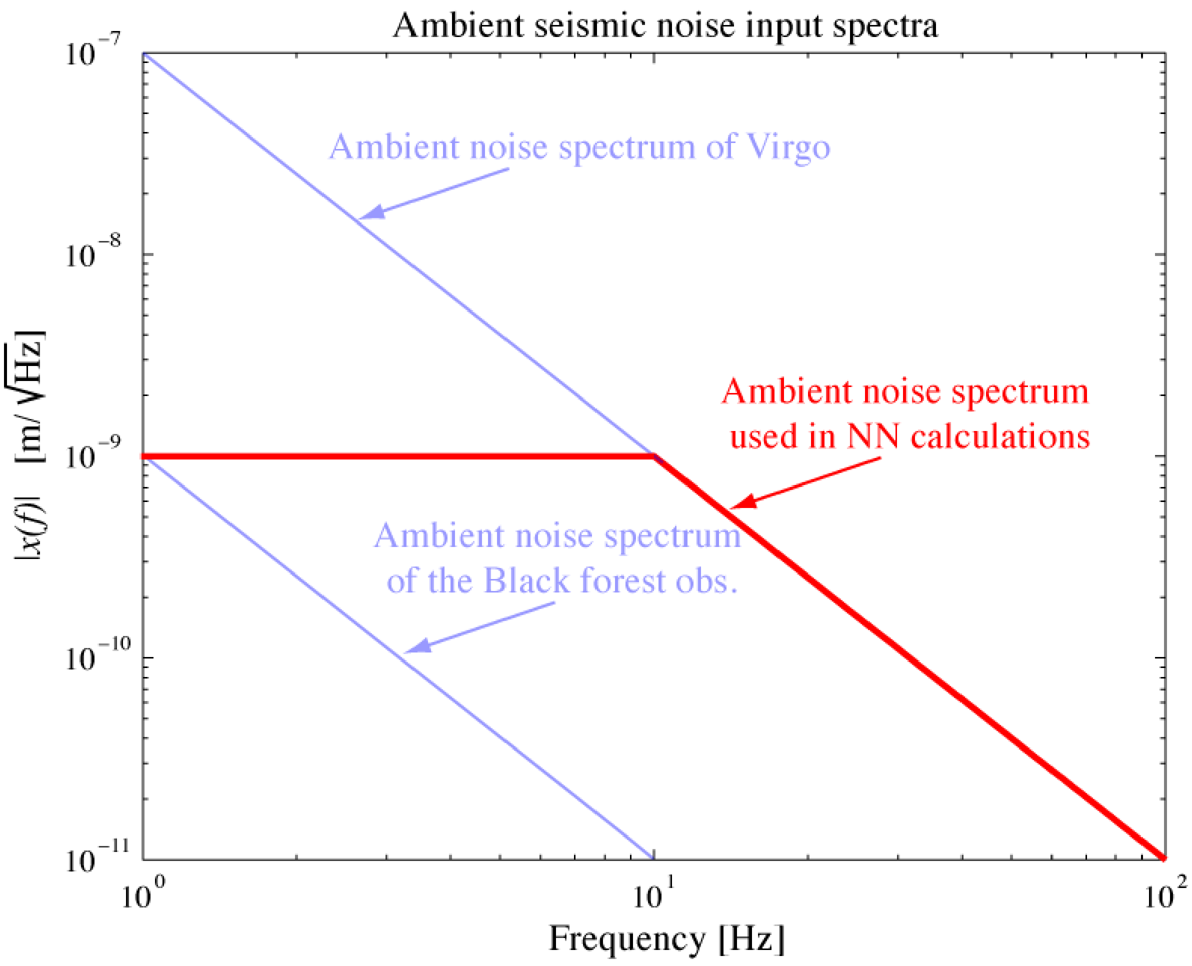
- For the FE model we can calculate the acceleration at our test point as:



$$\vec{a}(t) = \sum_{x,y,z} \frac{-G\rho\,\Delta V}{(x^2+y^2+z^2)^{(5/2)}} \times \begin{bmatrix} 2x^2-y^2-z^2 & 3xy & 3xz \\ 3yx & 2y^2-x^2-z^2 & 3yz \\ 3zx & 3zy & 2z^2-x^2-y^2 \end{bmatrix} \begin{bmatrix} u(t) \\ v(t) \\ w(t) \end{bmatrix}$$

Surface detector input spectra



- 1e-9 m/sqrt(Hz) between 1 and 10Hz
- 1e-9 m/sqrt(Hz) (1/f^2) from 10Hz

- We know that for Virgo this does not represent the ambient seismic spectrum below 10Hz.

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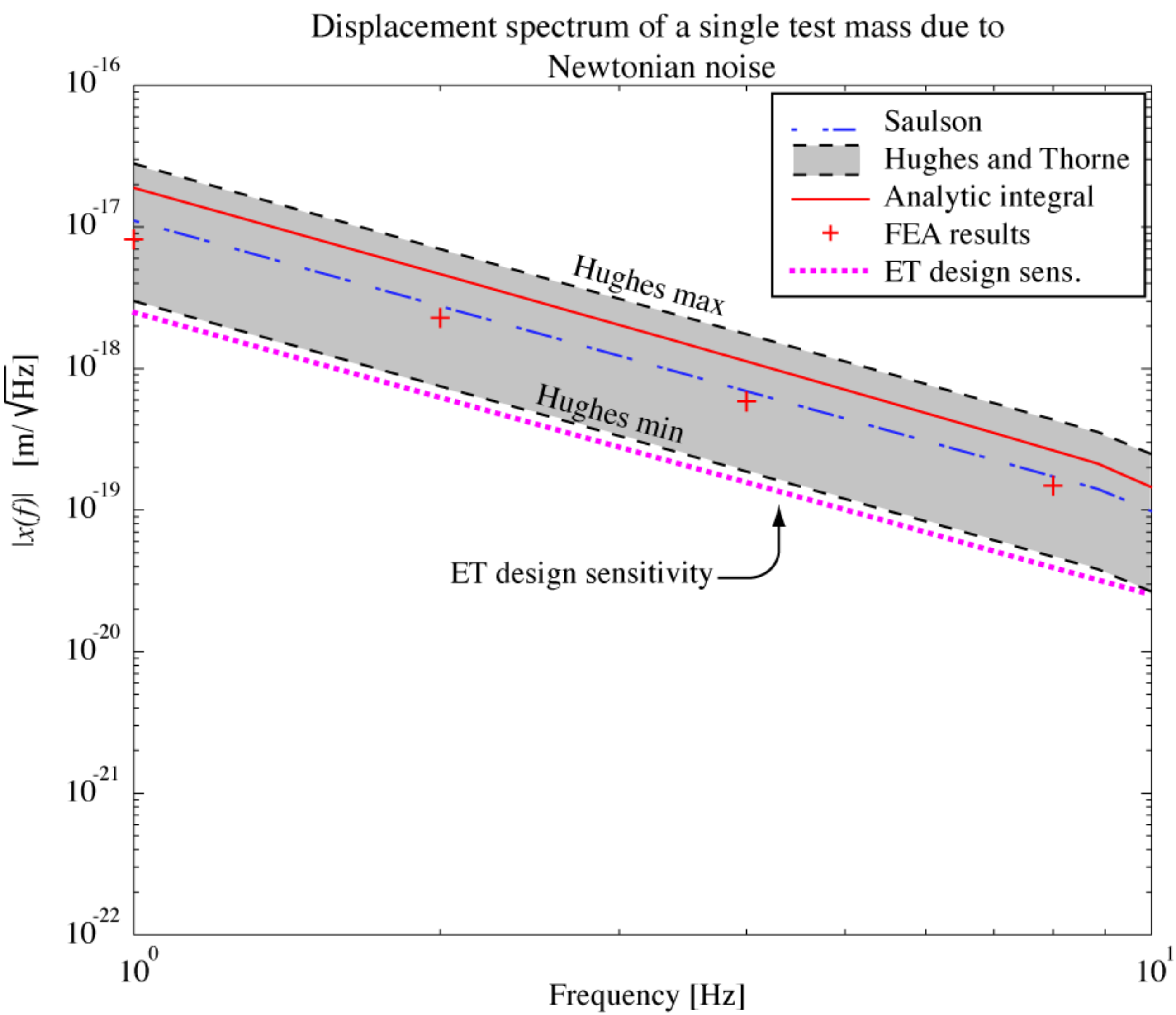

FE model input:

-Model dimensions:

1000 x 1000 x 1000m

E =80MPa

ρ =2000 kg/m^3

- Integration cut-off 50m

FE mode Output:

-Elements volumes

-Node coordinates:

x_i, y_i, z_i

-Node displacement:

$u_i(t)$, $v_i(t)$, $w_i(t)$

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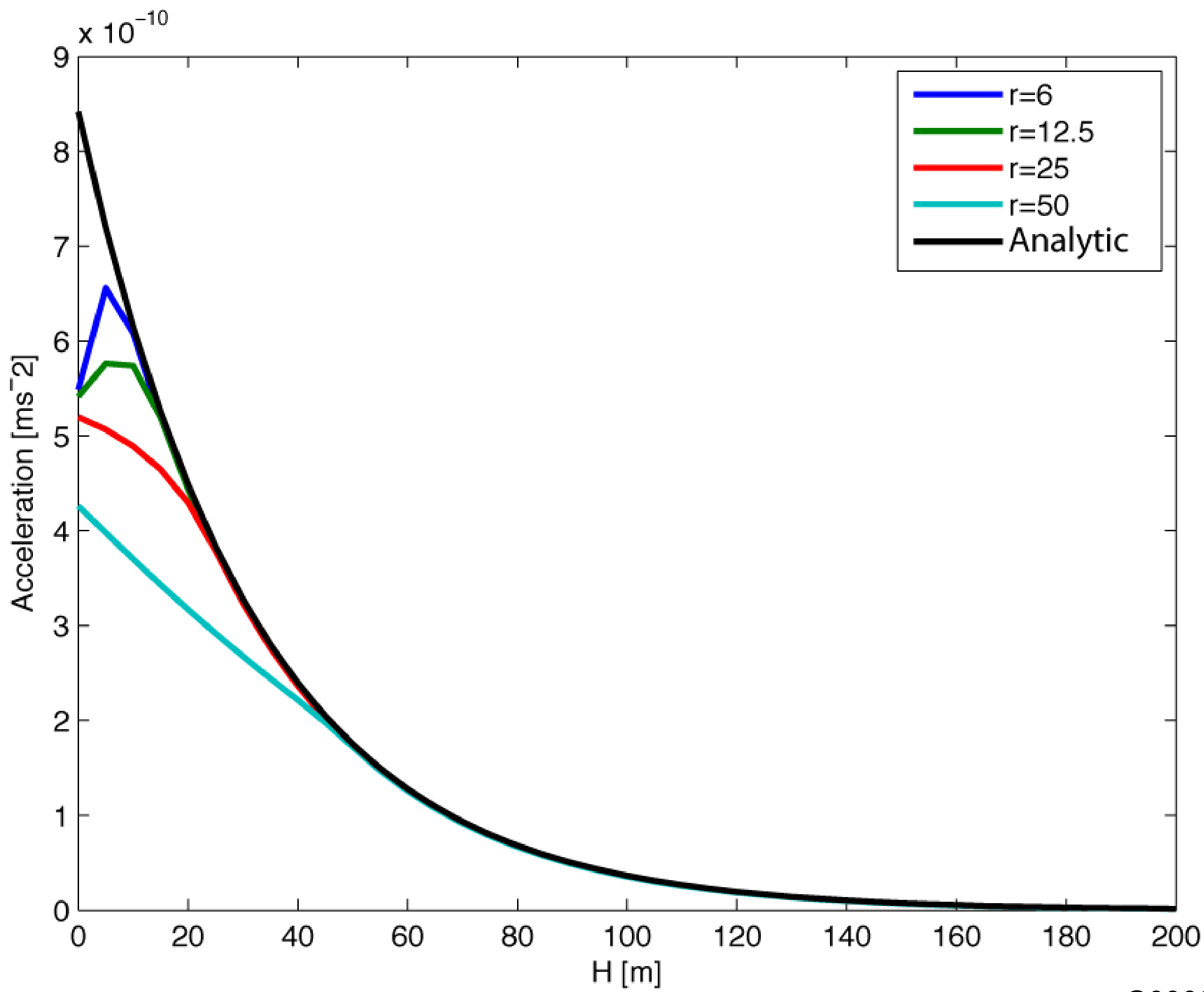

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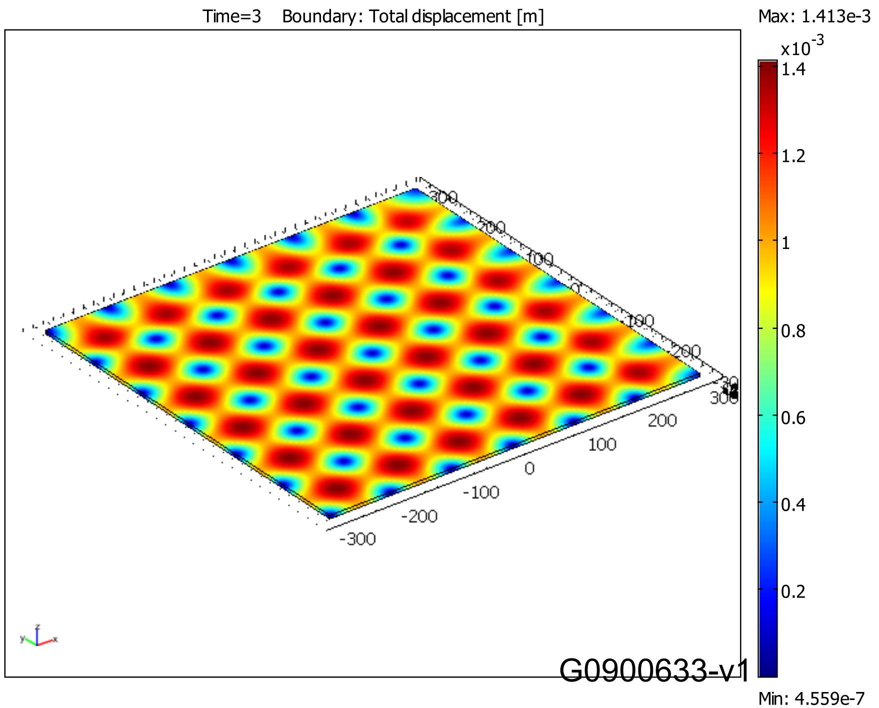
SEVENTH FRAMEWORK PROGRAMME

Geometric suppression

- Why underground?
  - Limit: contributions consistent with LNM
  - 0.1 nm/rtHz at 1 Hz
  - Cultural noise: dominated by surface waves
  - Geometric suppression through integration
- Geometric suppression
  - Surface layer: 3 km x 3 km x 50 m
  - Grid of 20 m x 20 m x 20 m
  - Cut-off 50 m
  - 2D compression waves
  - Wavelength 200 m
  - Integrate NN versus distance
- More realistic model
  - Surface wave amplitudes decay exponentially with depth
  - Include compression waves
  - Include incoherent sources



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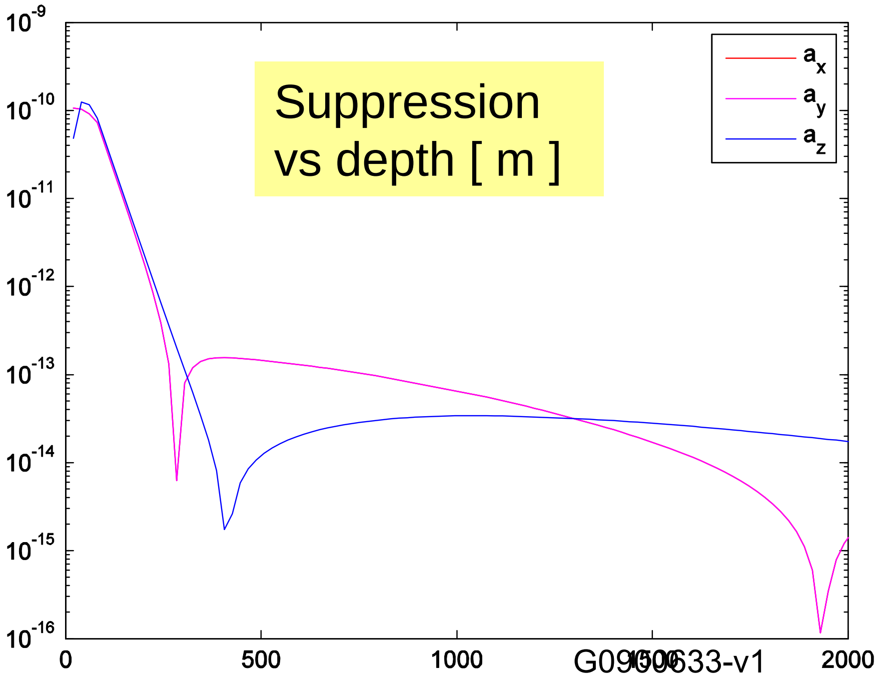
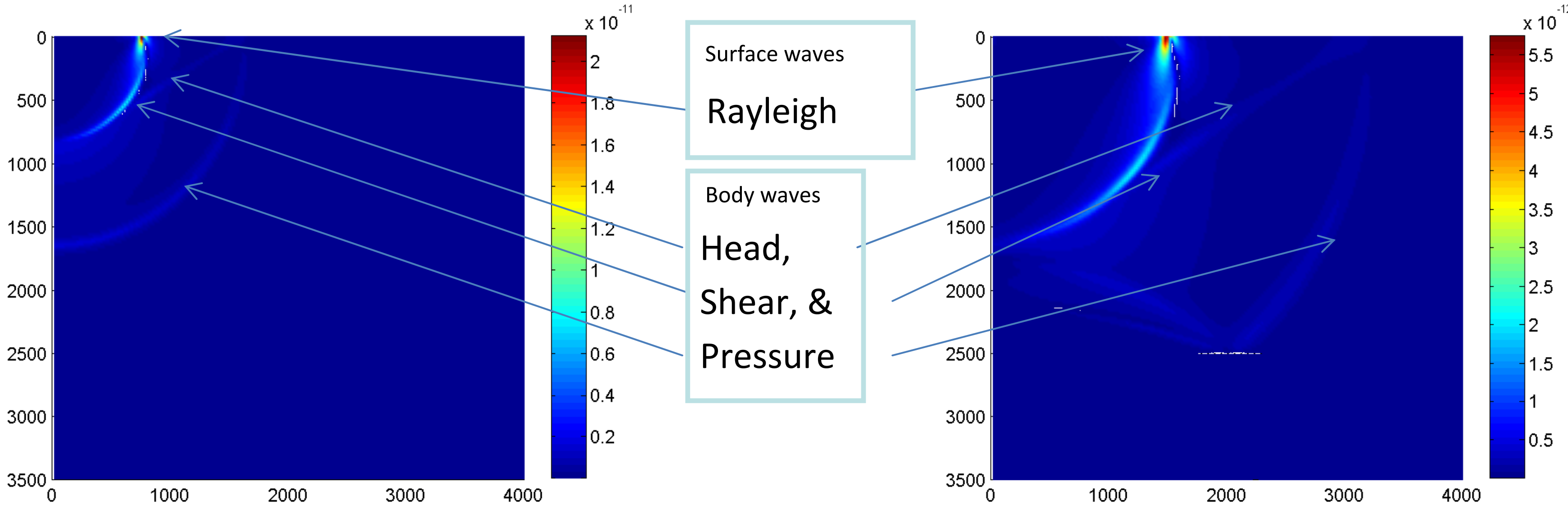
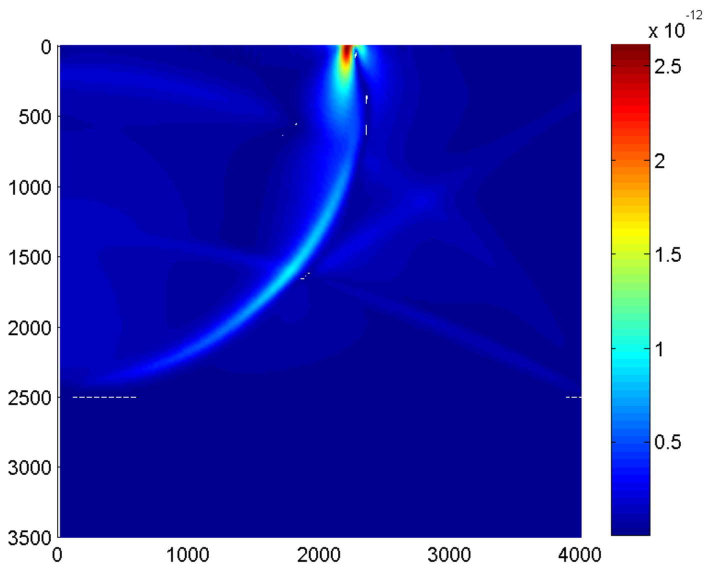
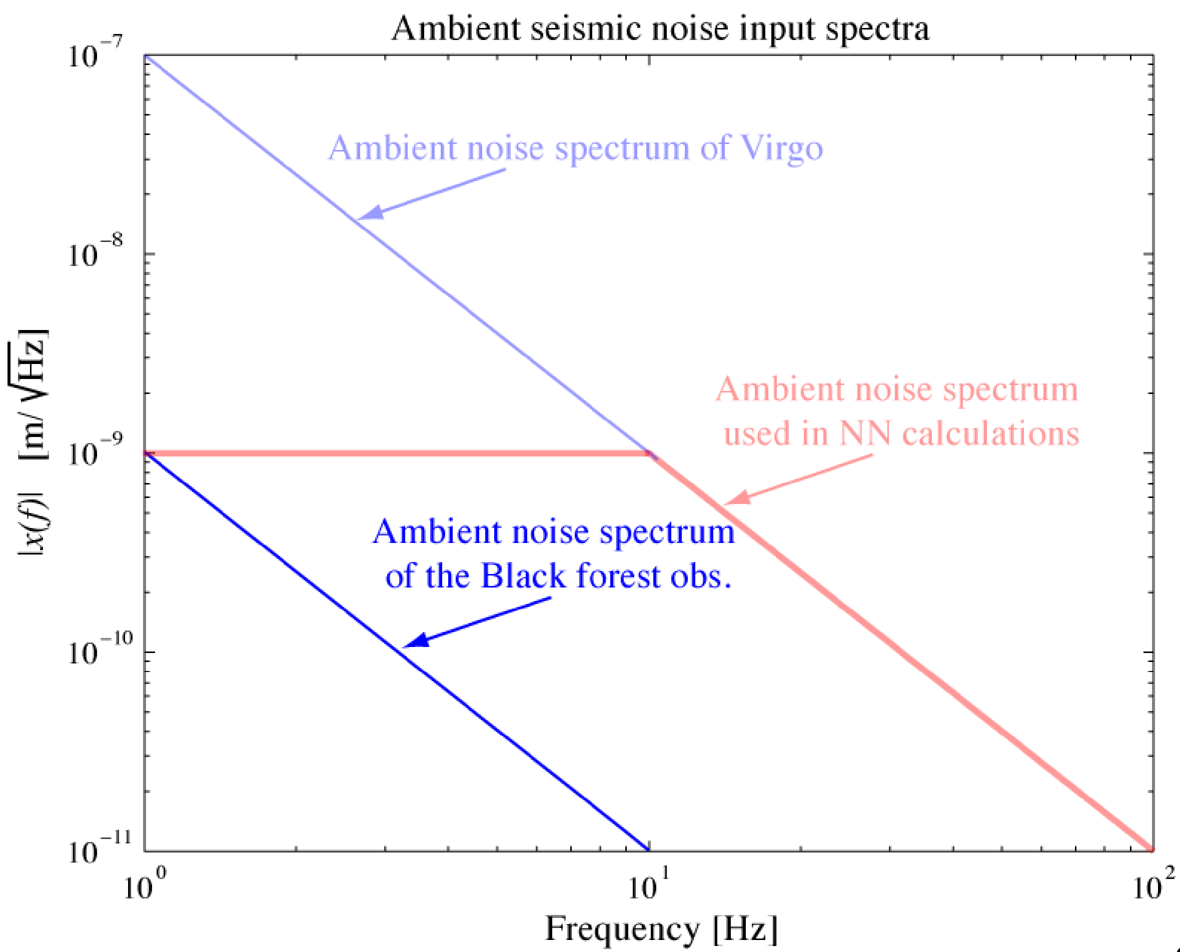






- Wave attenuation has two components
  - Geometrical (expansion of wave fronts) ~ r^n
    - Raleigh, n=-1/2
    - Body waves on surface, n=-2
    - Body waves at depth, n=-1
  - Material (damping).

Dummy calculation: Subterranean detector input spectra



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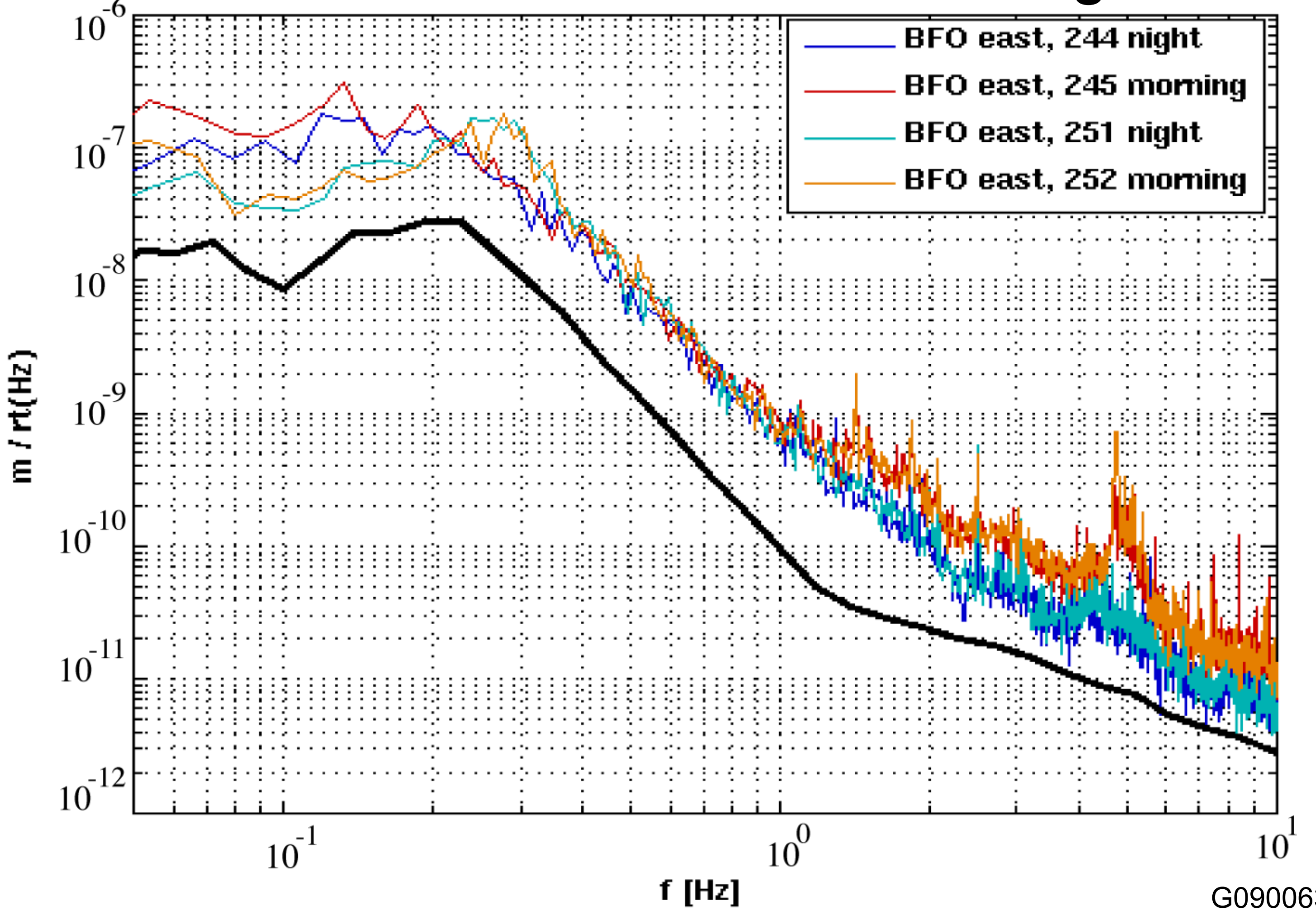
BLACK FOREST OBERVATORY

H. Grote: Gran Sasso WP1 Meeting 2009



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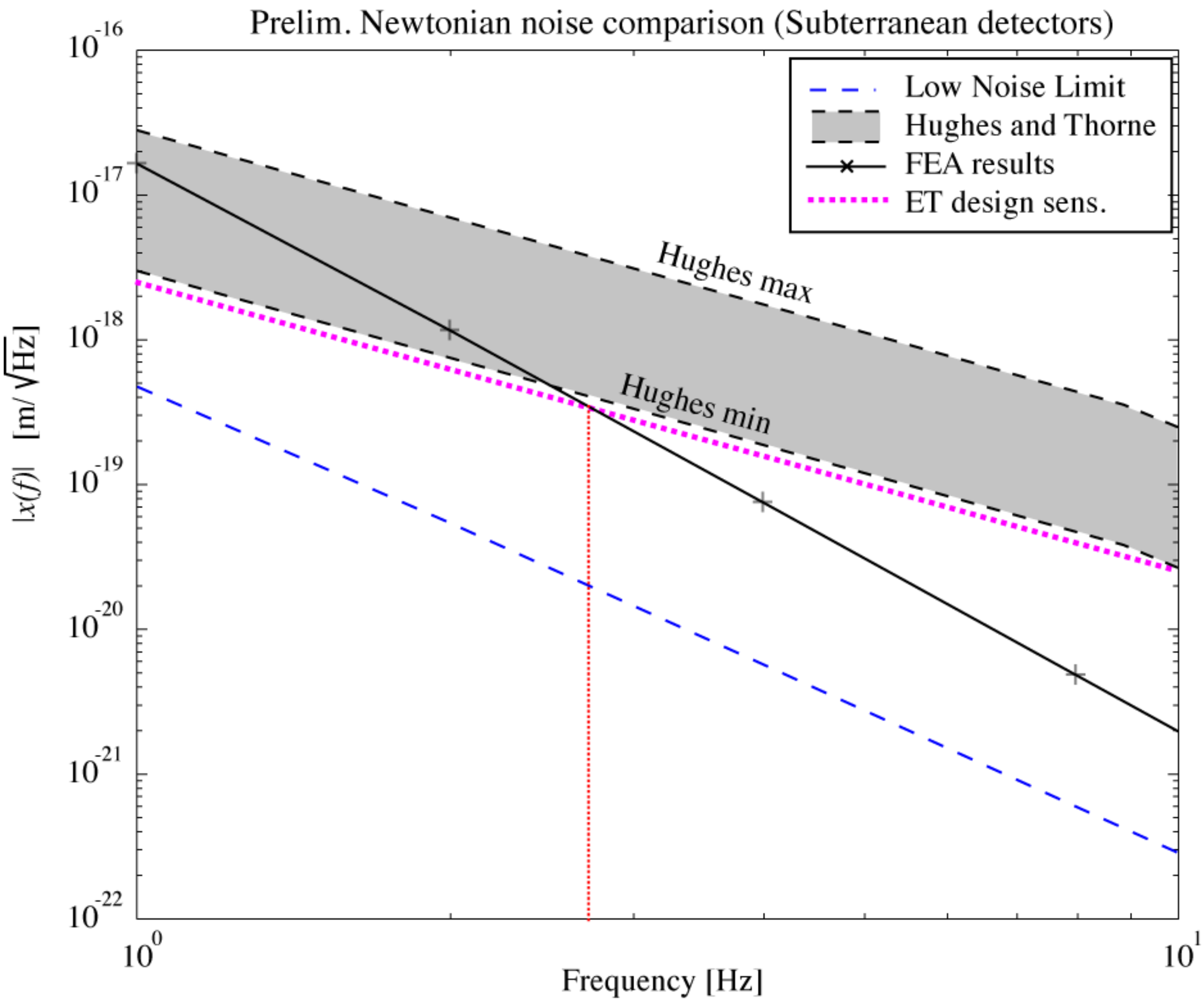
SEVENTH FRAMEWORK PROGRAMME

Dummy calc: Displacement sensitivity for a single test mass



FE model input:

-Model dimensions:

1000 x 1000 x 1000m

E =80MPa

ρ =2000 kg/m^3

- Integration cut-off 50m

FE mode Output:

-Elements volumes

-Node coordinates:

x_i, y_i, z_i

-Node displacement:

$u_i(t)$, $v_i(t)$, $w_i(t)$

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- Future models should represent realistic geology (apply a Young's mod variation in soil layers).
- Test cavity geometries in homogeneous and inhomogeneous half spaces.
- Using complex a geology, test "seismo-meter" arrays to look at active subtraction schemes.

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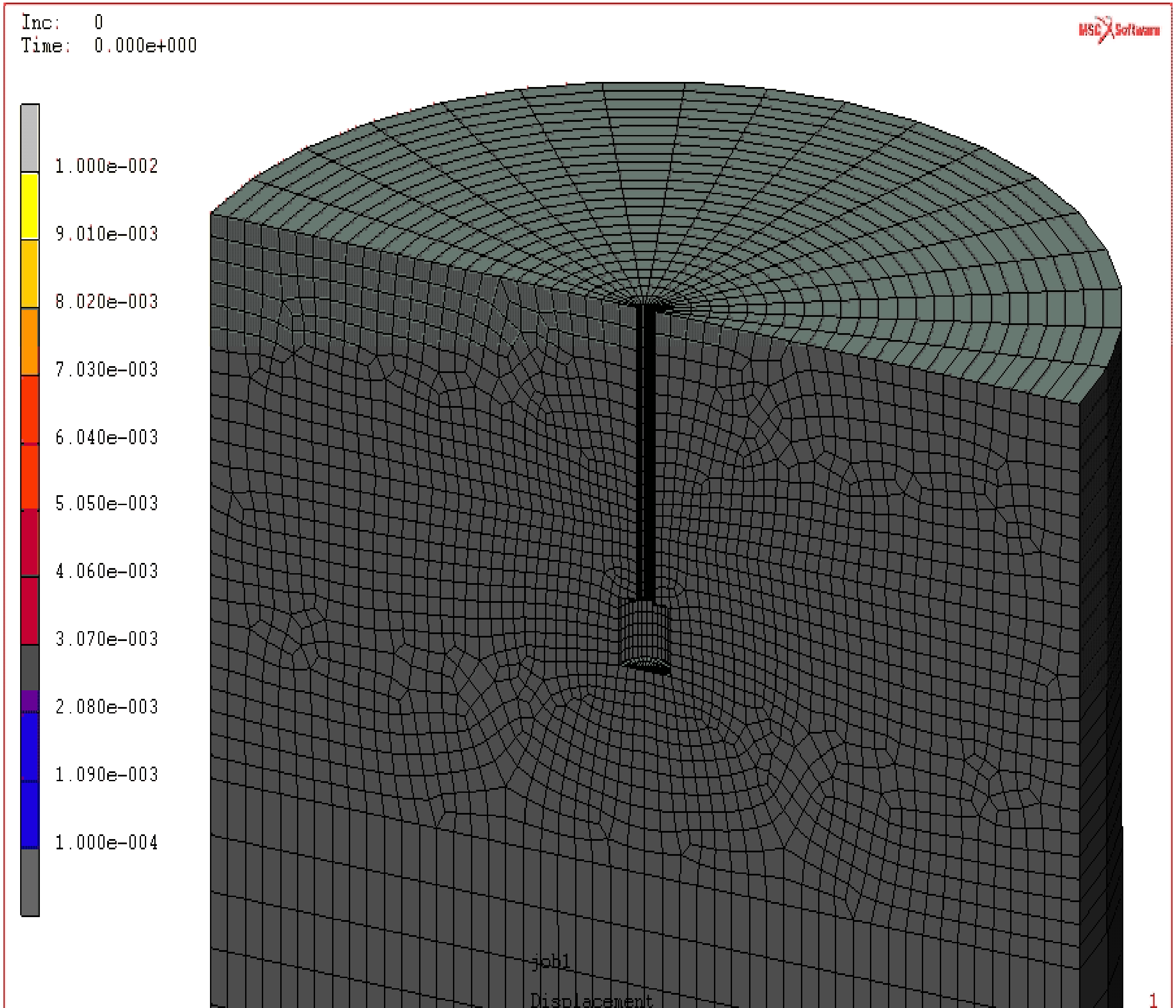

FEM input:

- 200m clay:
  E =80MPa
  ρ =3000 kg/m^3
- 1300m granite:
  E =20GPa
  ρ = 3000 kg/m^3
- cavity:
  depth 260m
  Ø50m

FEM Output:

-Elements volumes
-Node coordinates:
  x_i, y_i, z_i
-Node displacement:
  $u_i(t)$, $v_i(t)$, $w_i(t)$

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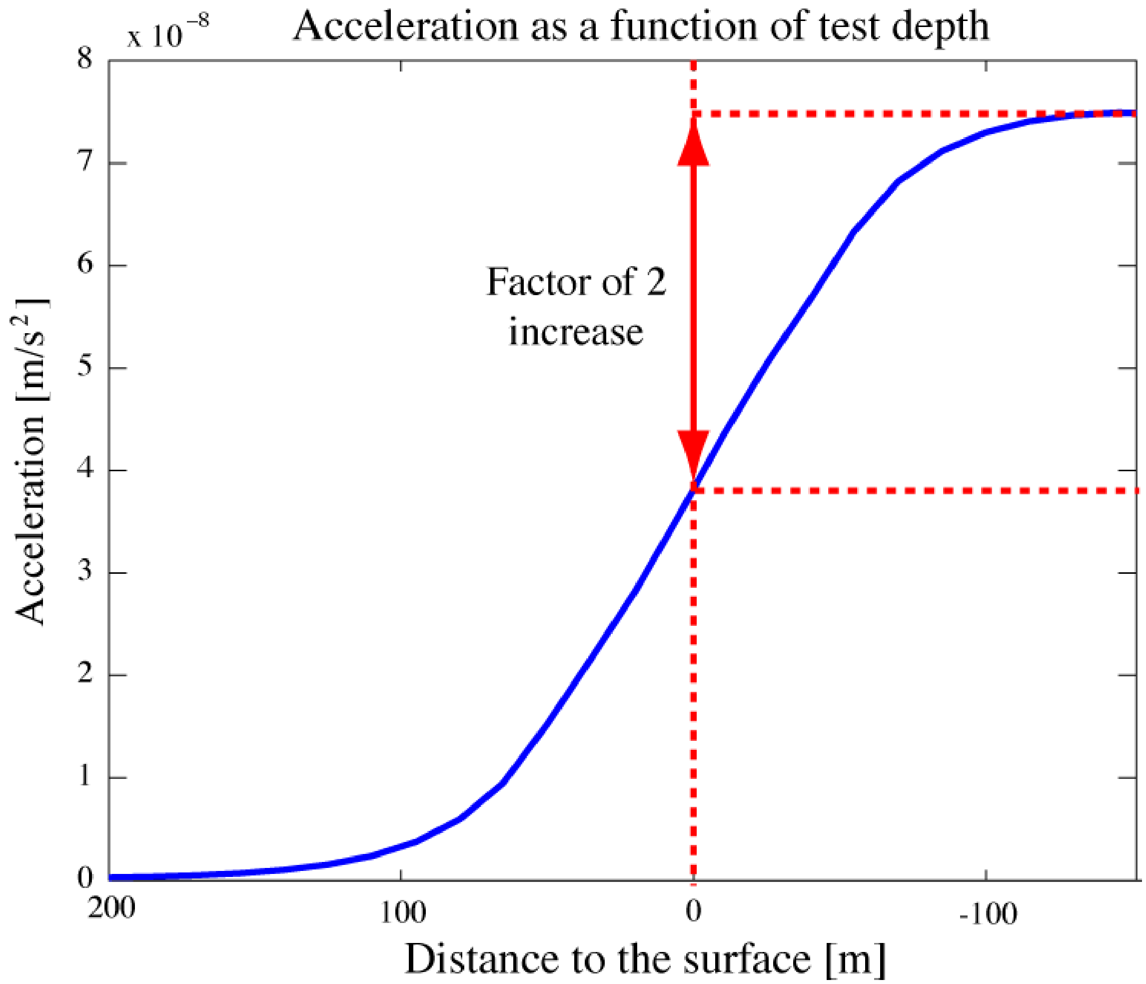
Checking the acceleration at various test depths



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