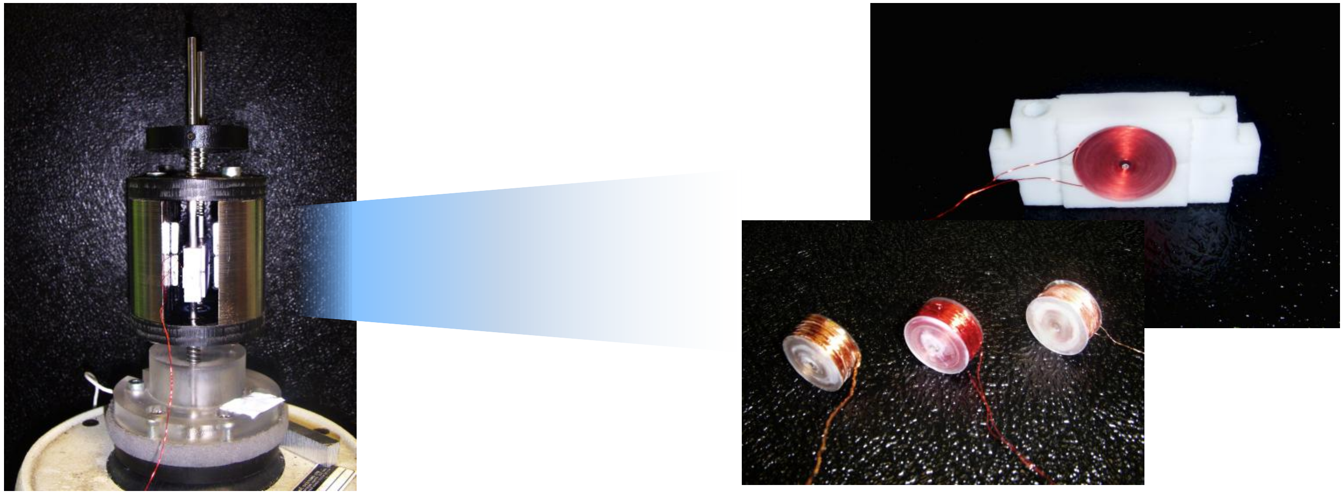
18/07/14

NiPS Summer school 2014-ICT Workshop

Characterization and optimization of a 2DOF velocity amplified EM-EH

Elisabetta Boco, *Valeria Nico, Declan O'Donoghue, Ronan Frizzell, Gerard Kelly, Jeff Punch*



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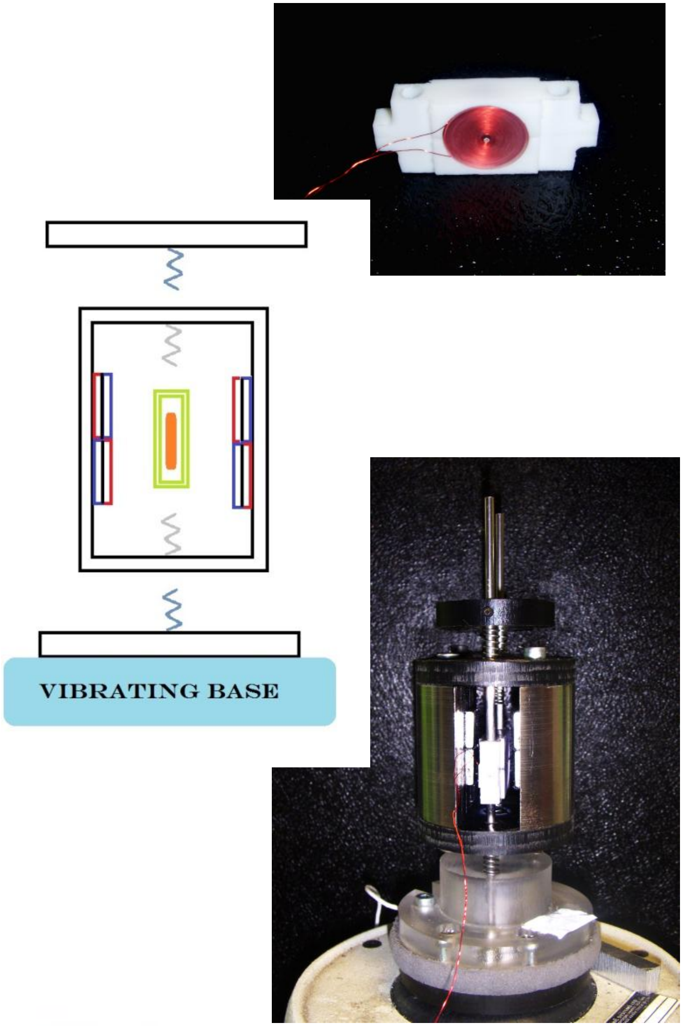
Outline

1. The harvester
2. Characterization through transfer functions of the inner mass system
   - Sine sweep of increasing frequency data
   - Comparison with decreasing frequency: hysteresis
3. Same analysis for the whole system
4. Optimization Process
   - Configuration
   - Output voltage and power comparison at each acceleration

The Harvester



- Two masses system: collisions between the inner small mass, and the outer bigger one, provide velocity amplification

- A coil is embedded in the inner mass. It is oscillating between two sets of magnets providing a strong magnetic field in the area.

$$e.m.f. = -\frac{\partial \phi}{\partial t}$$

- The presence of two masses enlarges the bandwidth of the system, along with the periodic disconnection of the two masses from the springs.

Characterization: the transfer function

Let x(t) be the input and y(t) be the output of our system

$$X(s) = \int_{-\infty}^{\infty} x(t) e^{-st} dt$$

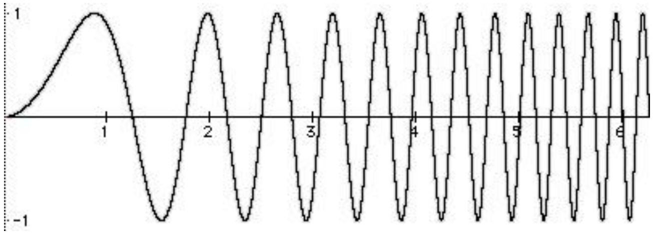
$$Y(s) = \int_{-\infty}^{\infty} y(t) e^{-st} dt$$

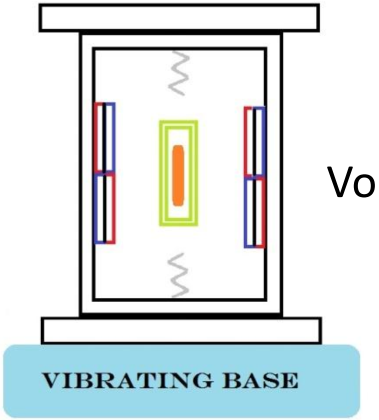
$$H(s) = \frac{Y(s)}{X(s)}$$

The Laplace transform is the Fourier transform when s=jω

H(s) is the TF only for linear systems: in nonlinear systems is H(x(t),ω). So, calculating the TF at different amplitudes of input, can show if the system is linear

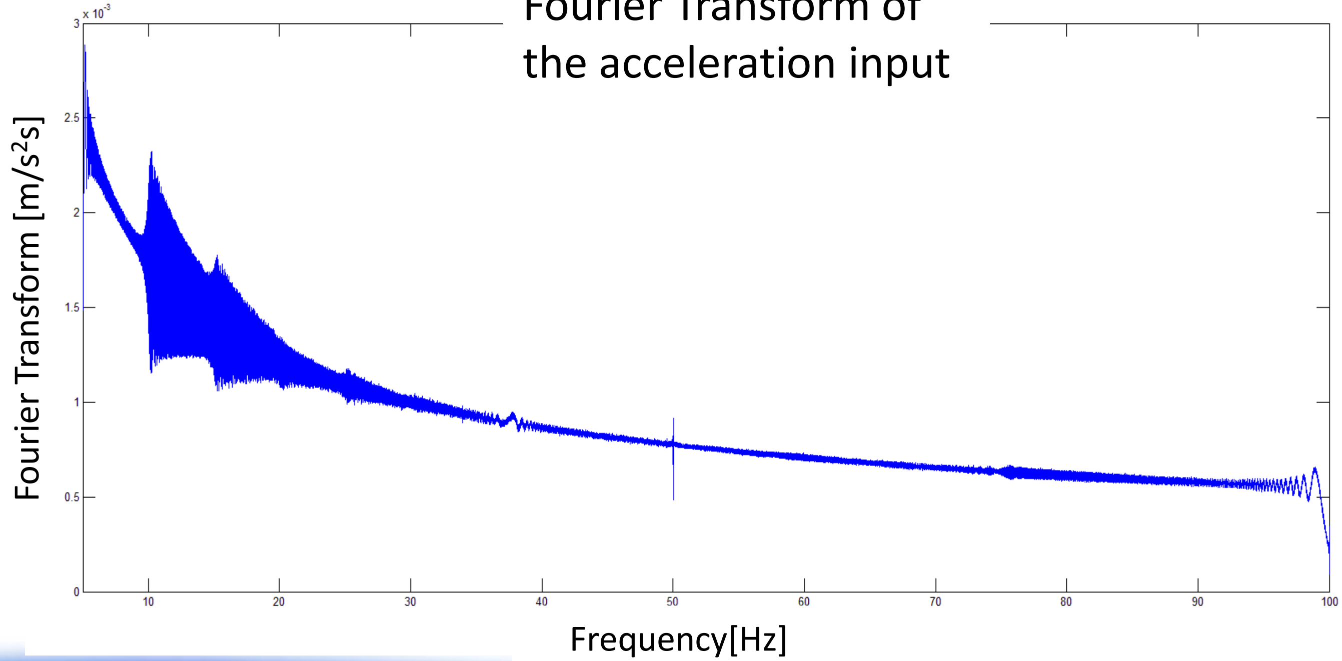
Constant acceleration input



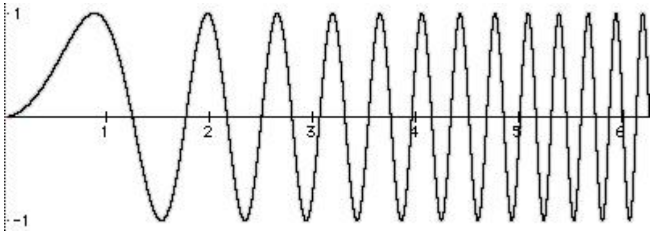


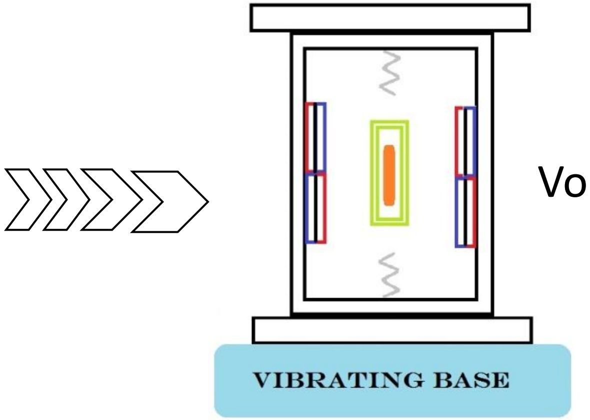
Voltage Output

Fourier Transform of the acceleration input



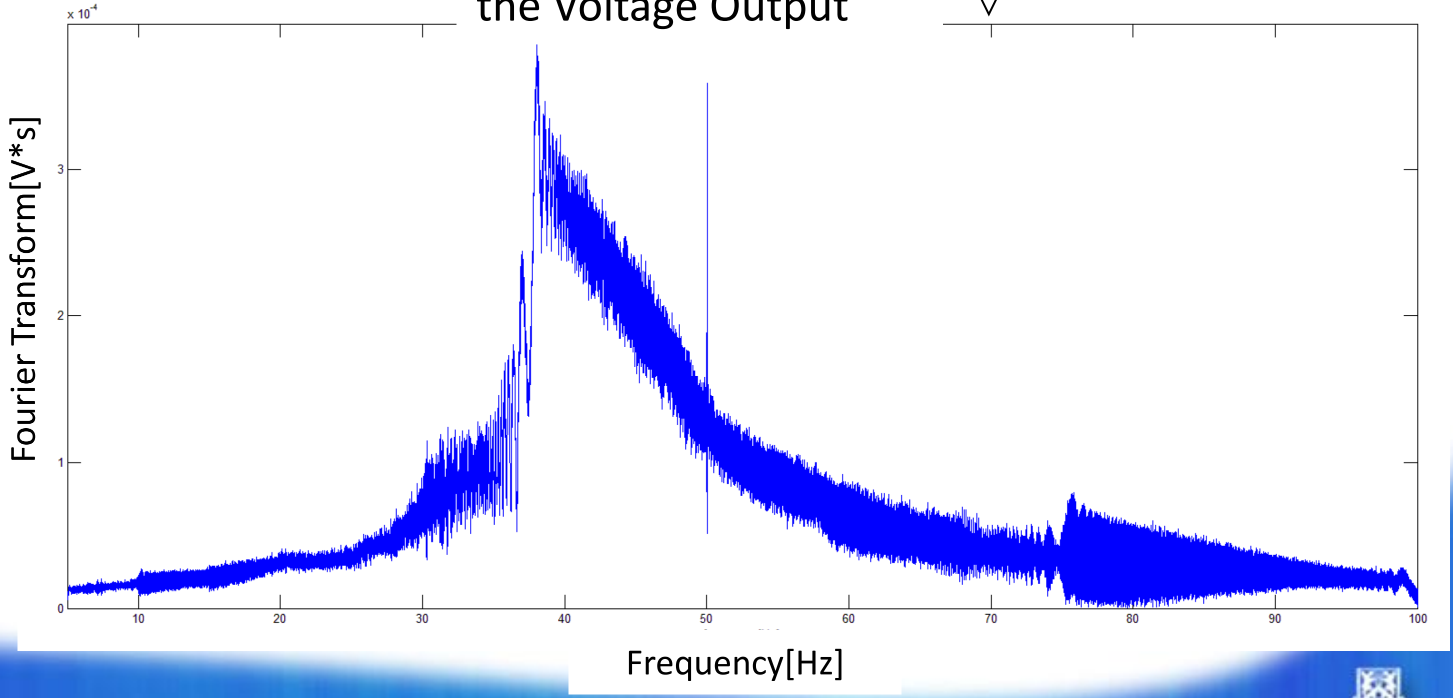
Constant acceleration input

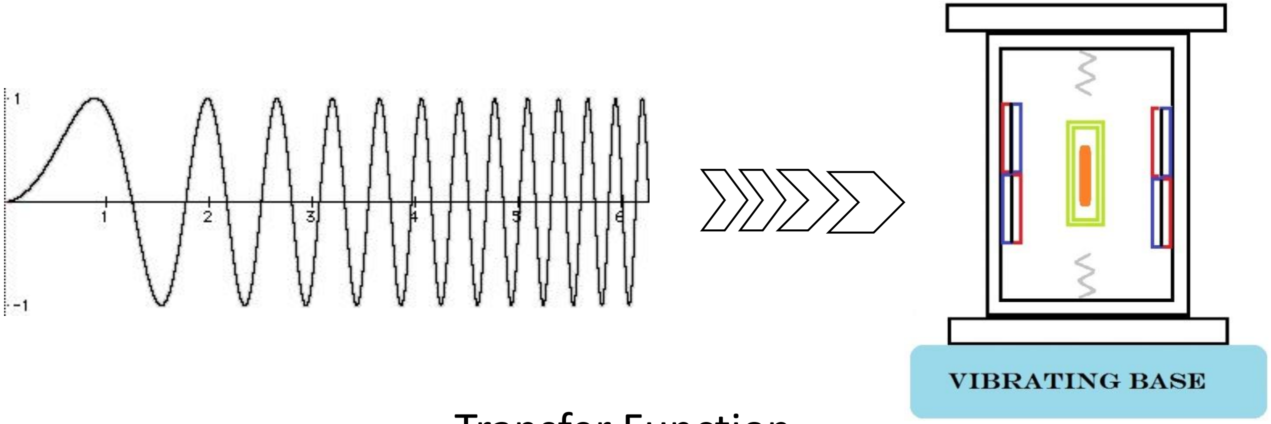


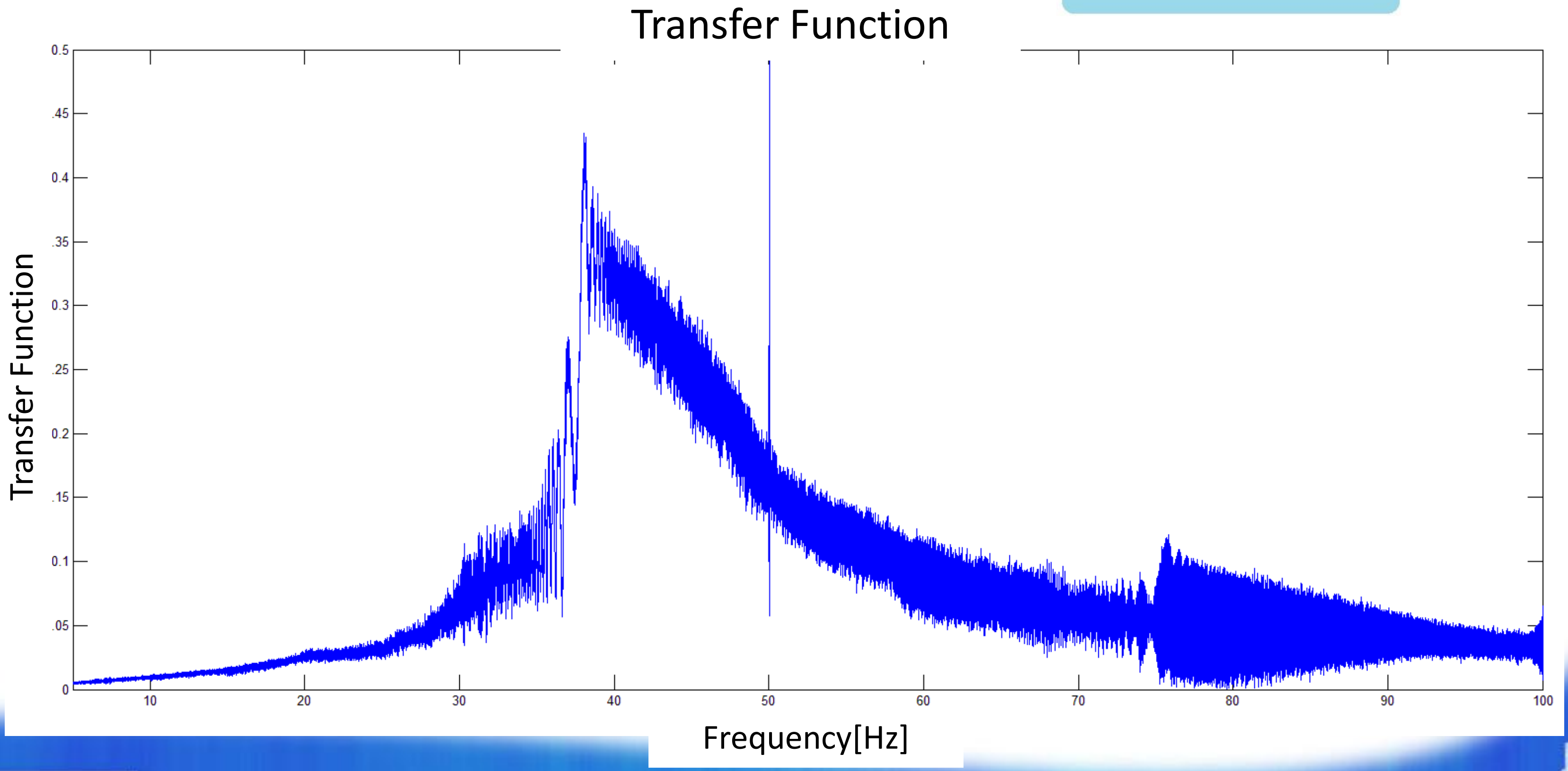


Voltage Output

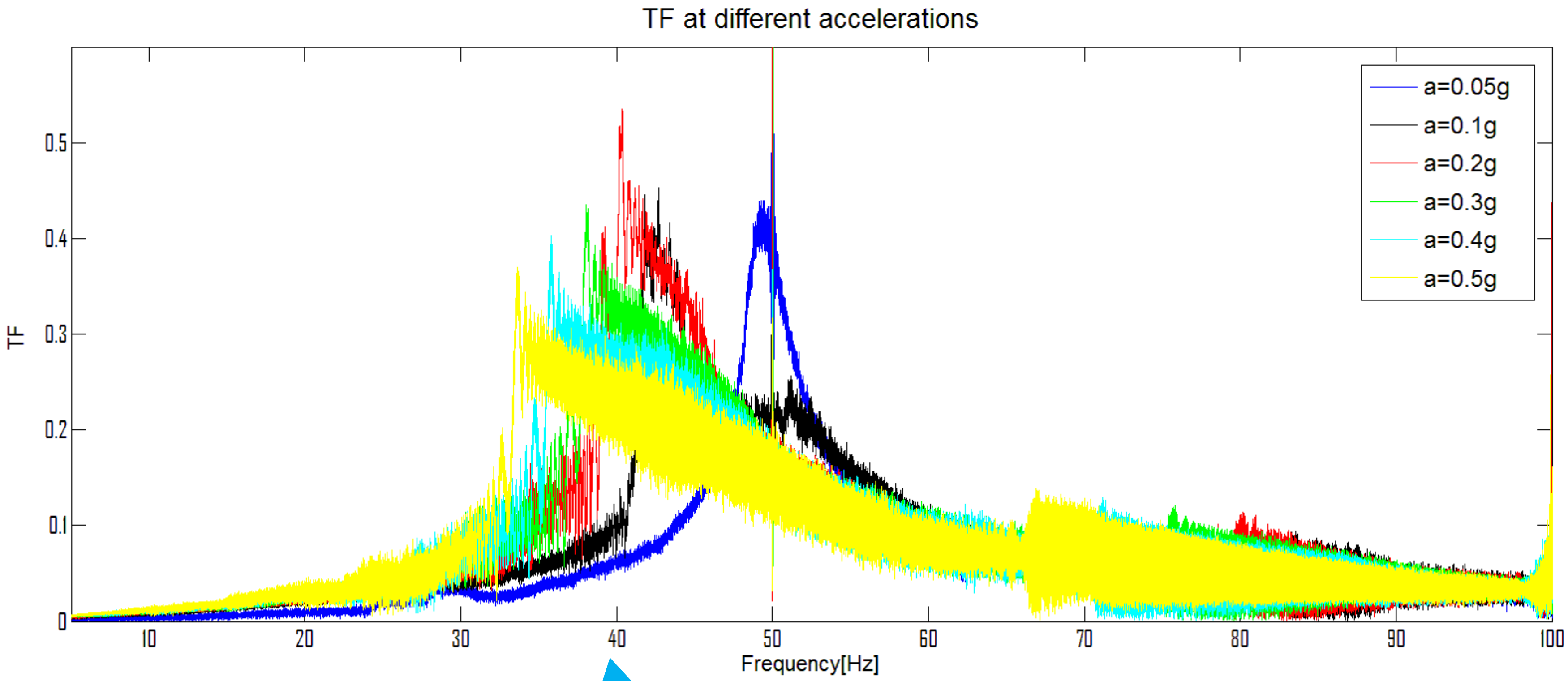
Fourier Transform of the Voltage Output




1
-1
1
2
3
4
5
6
VIBRATING BASE

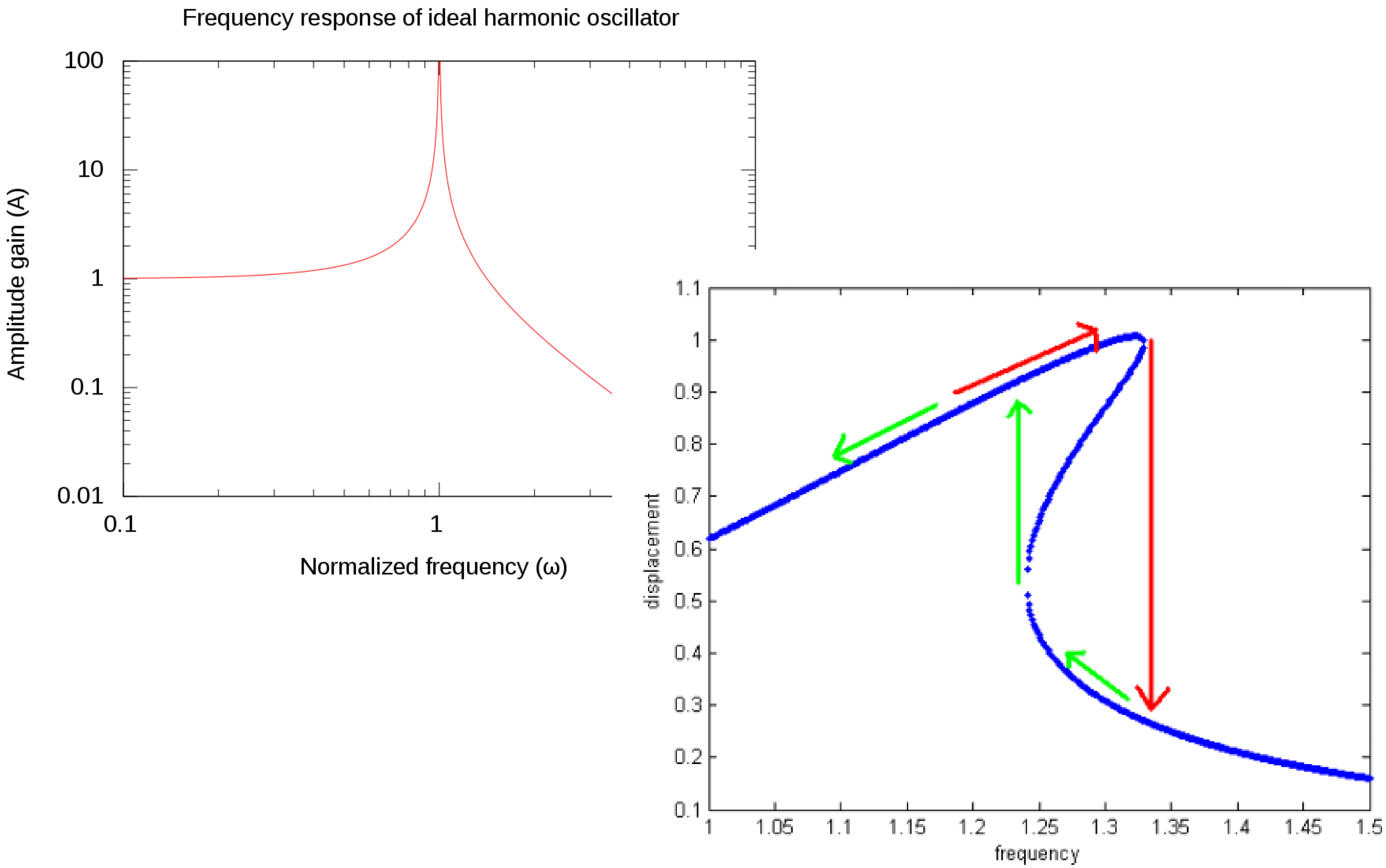

Transfer Function
Transfer Function
Frequency[Hz]
0.5
.45
0.4
.35
0.3
.25
0.2
.15
0.1
.05
0
10
20
30
40
50
60
70
80
90
100

Nonlinearity through TF: shifting

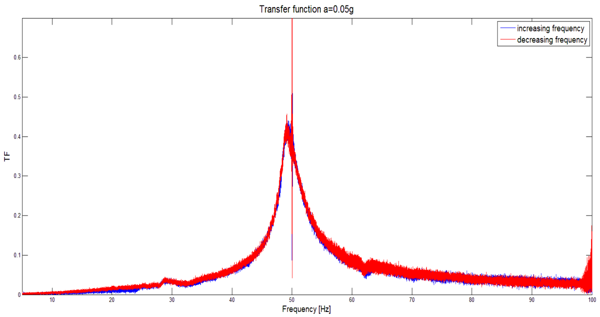


The stiffness “decreases”
interesting for small devices!

The hysteresis phenomenon



Nonlinearity through TF: hysteresis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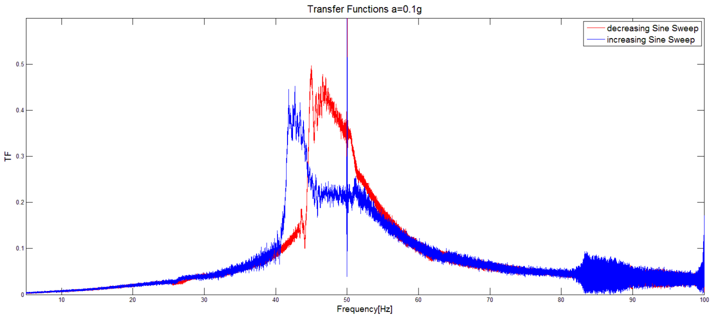
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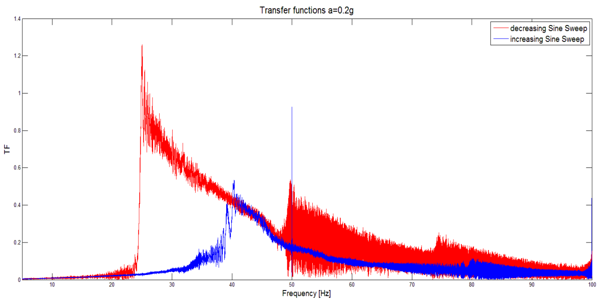
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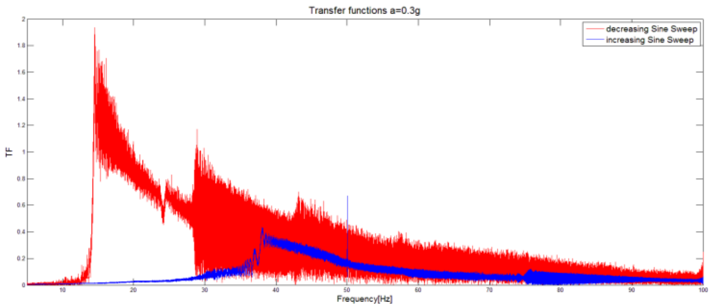
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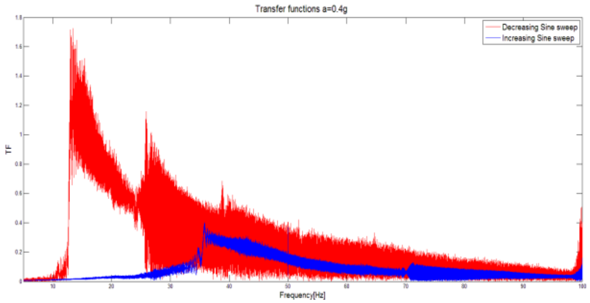
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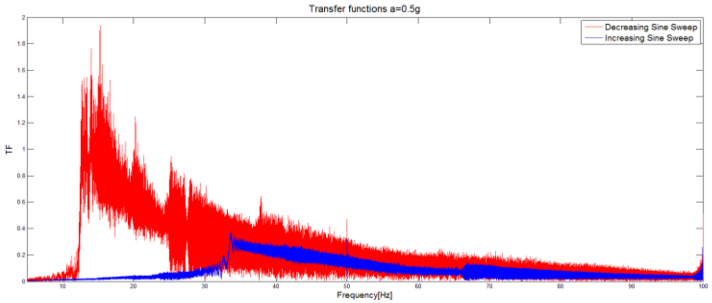
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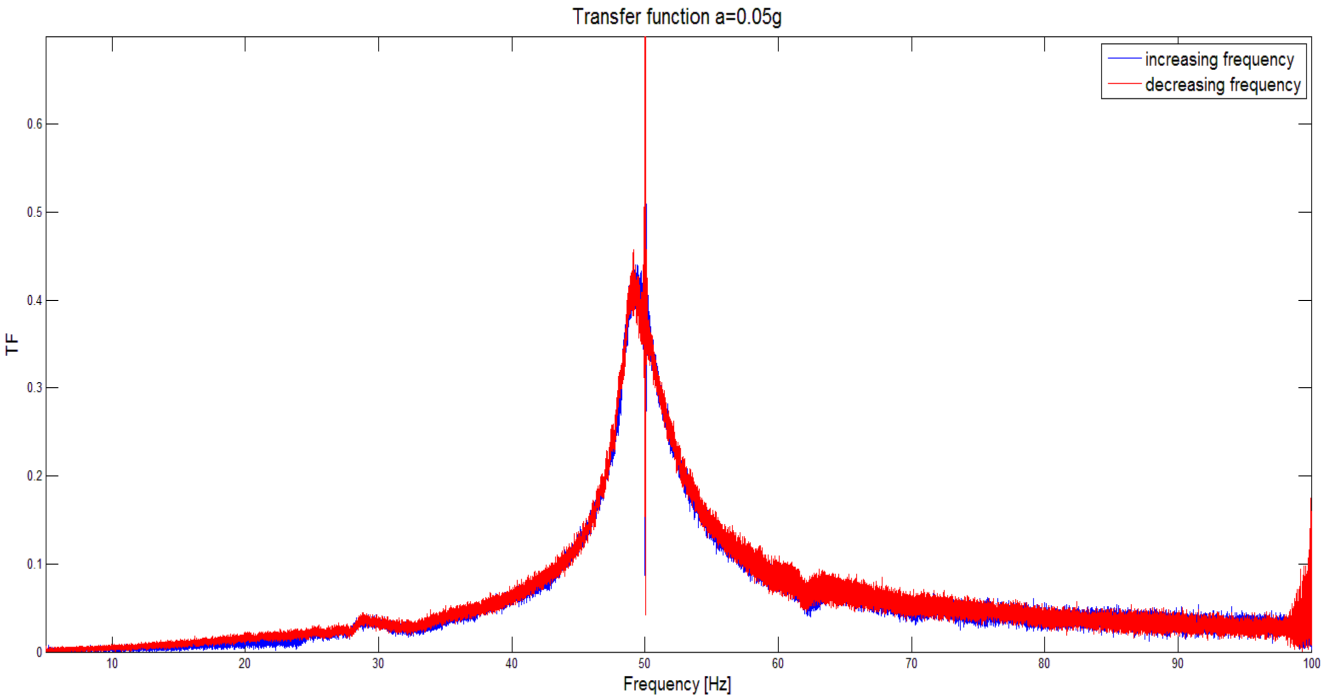
Nonlinearity through TF: hysteresis



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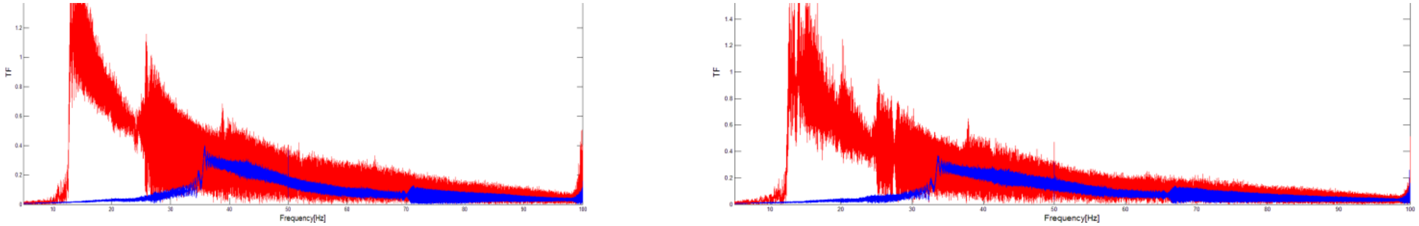

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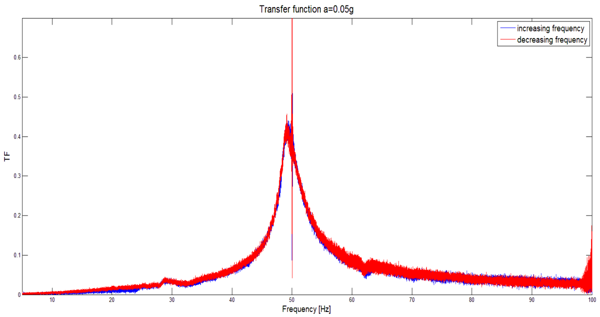
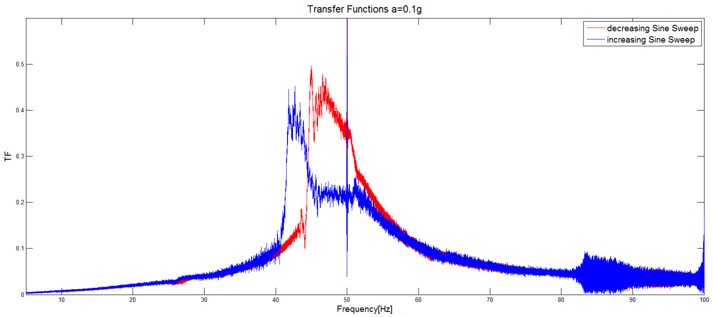
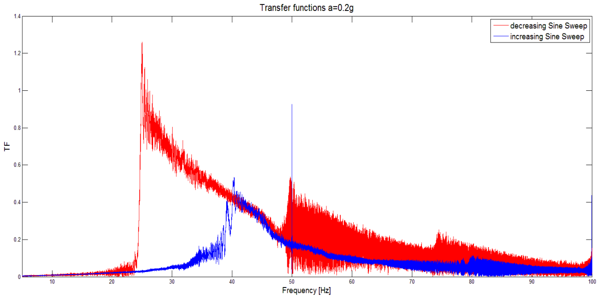
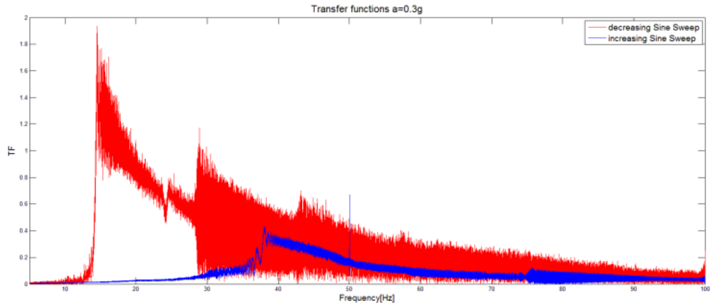
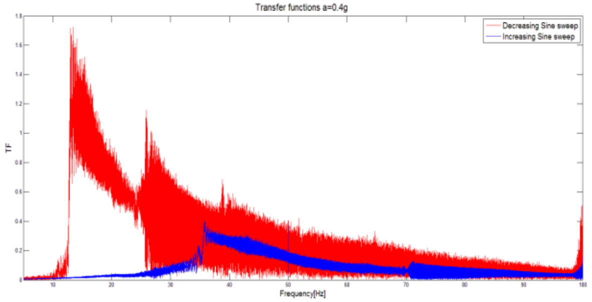
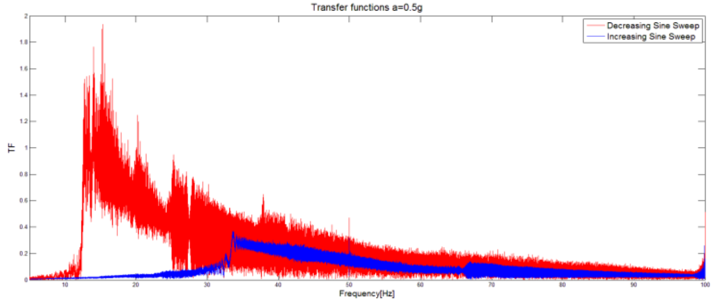




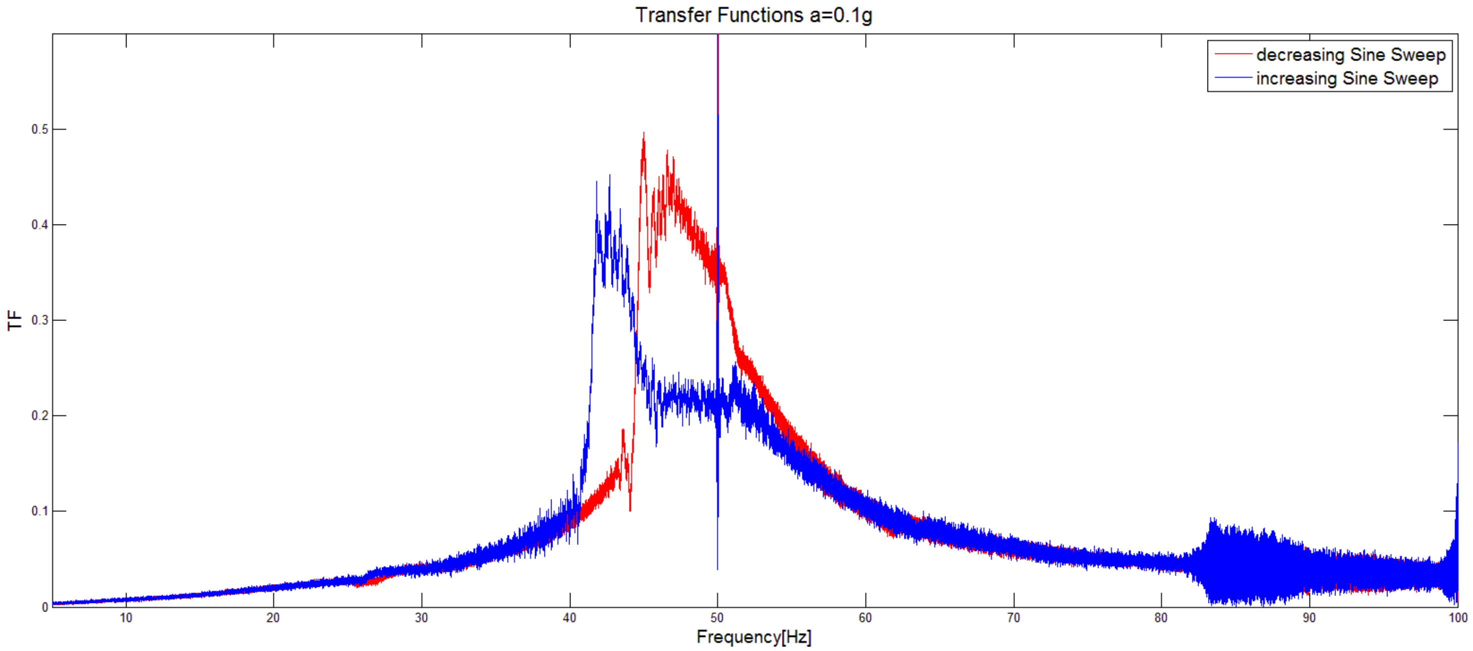


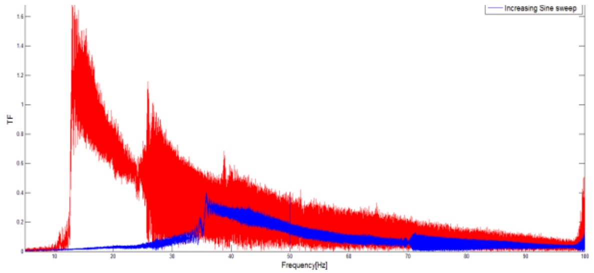


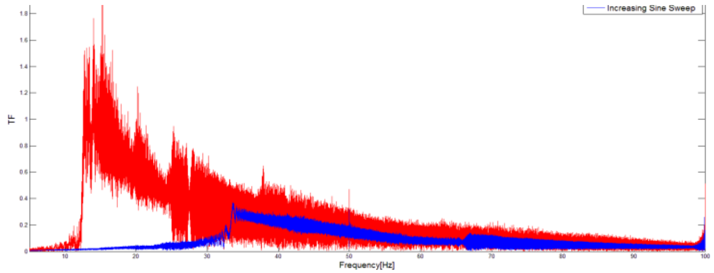




Nonlinearity through TF: hysteresis







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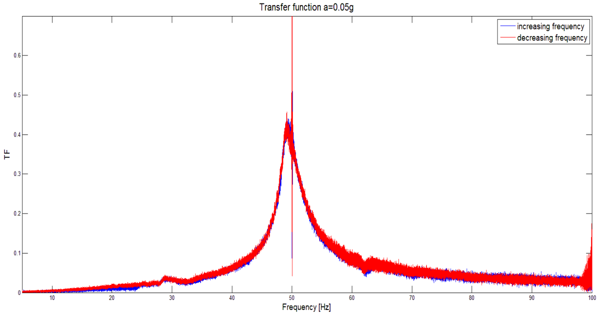

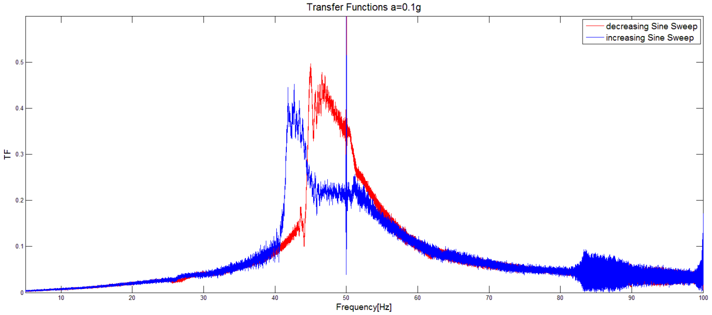

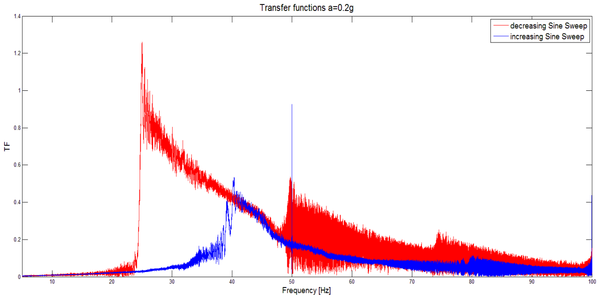

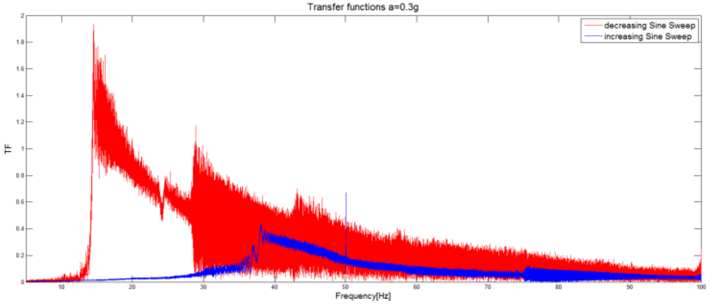

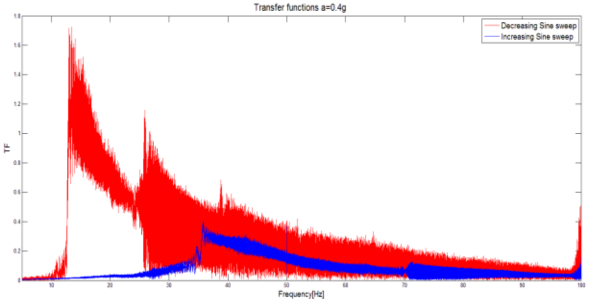

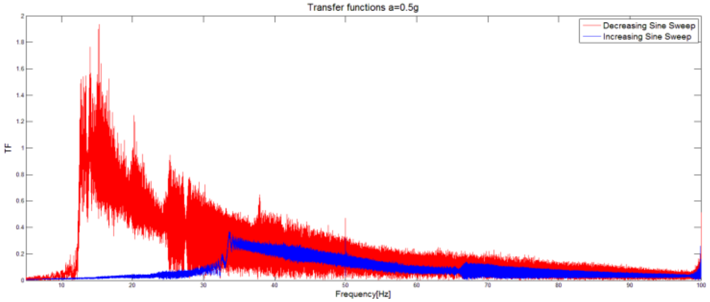

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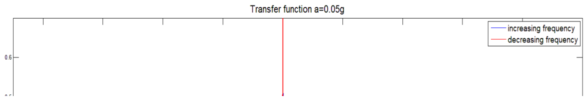
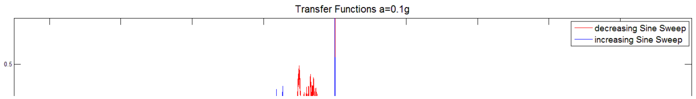
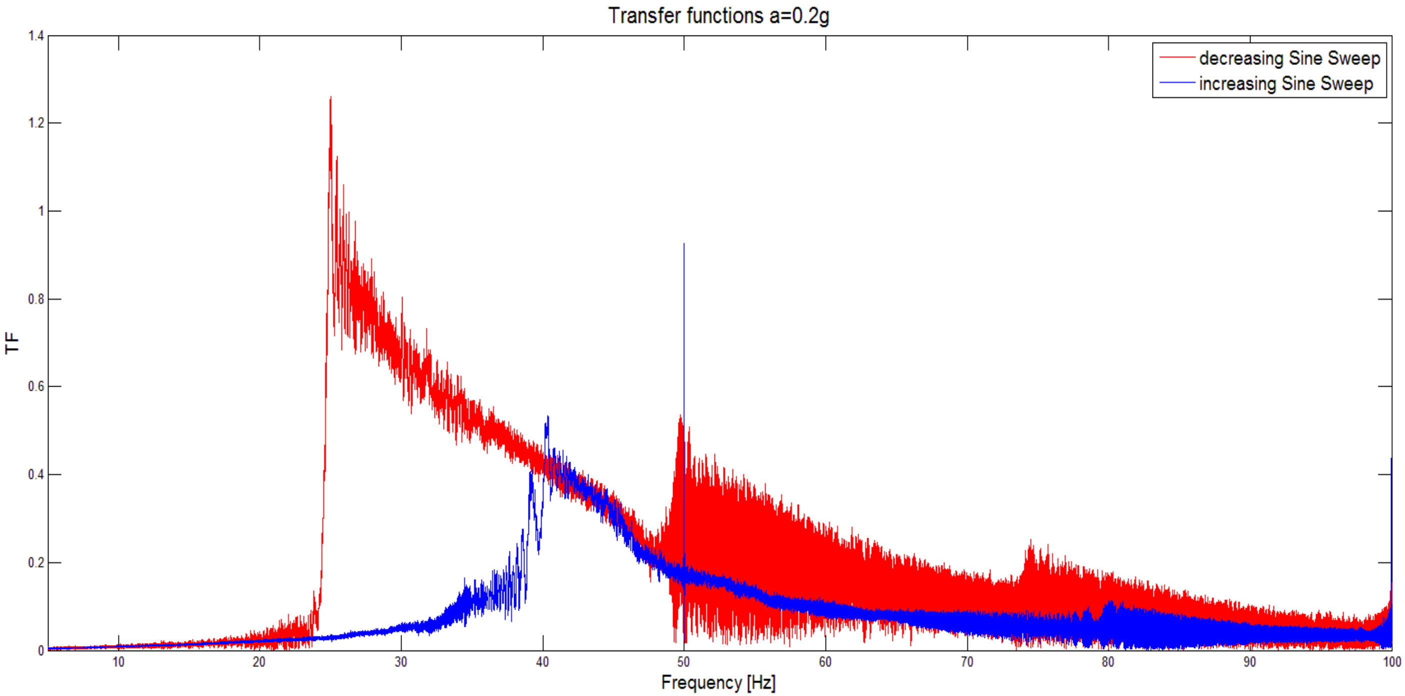
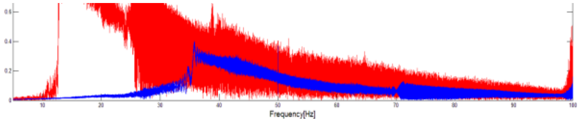
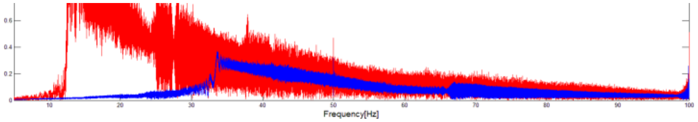


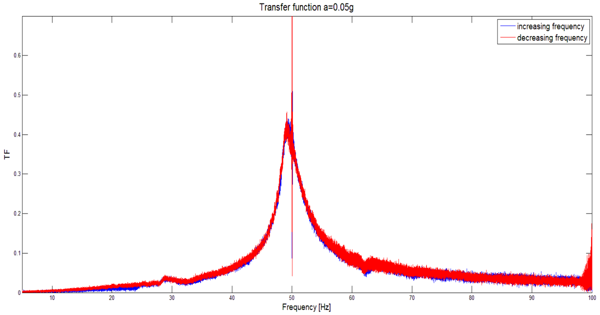








Nonlinearity through TF: hysteresis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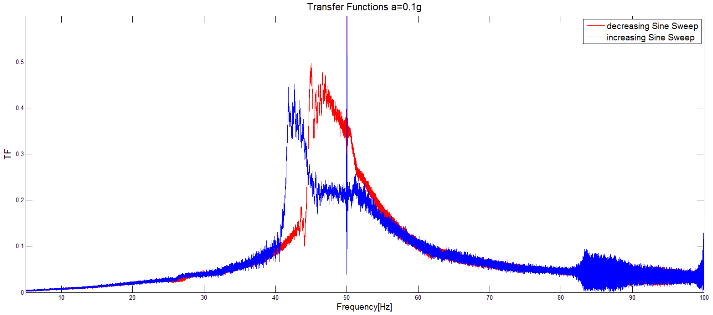
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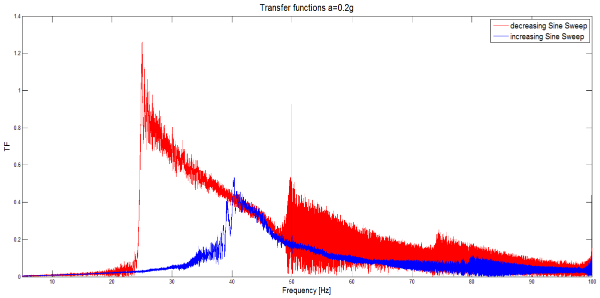
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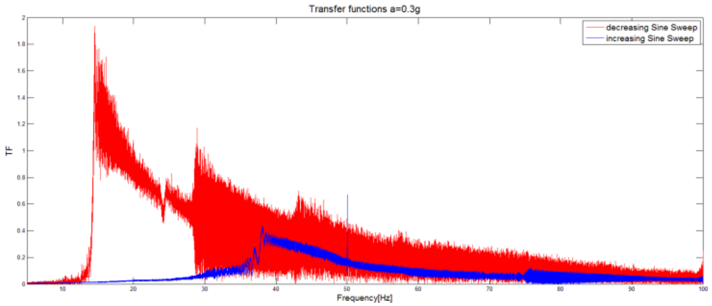
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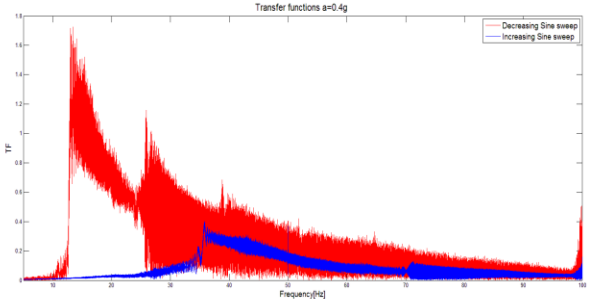
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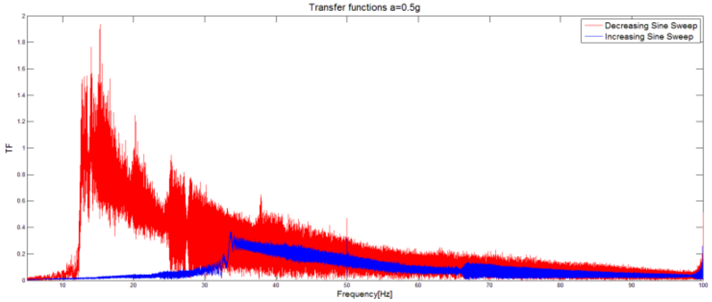
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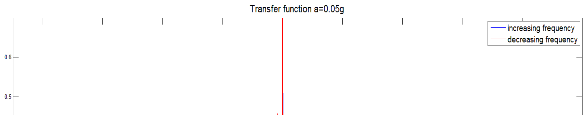
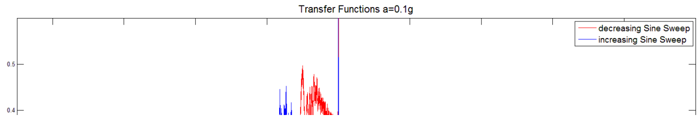
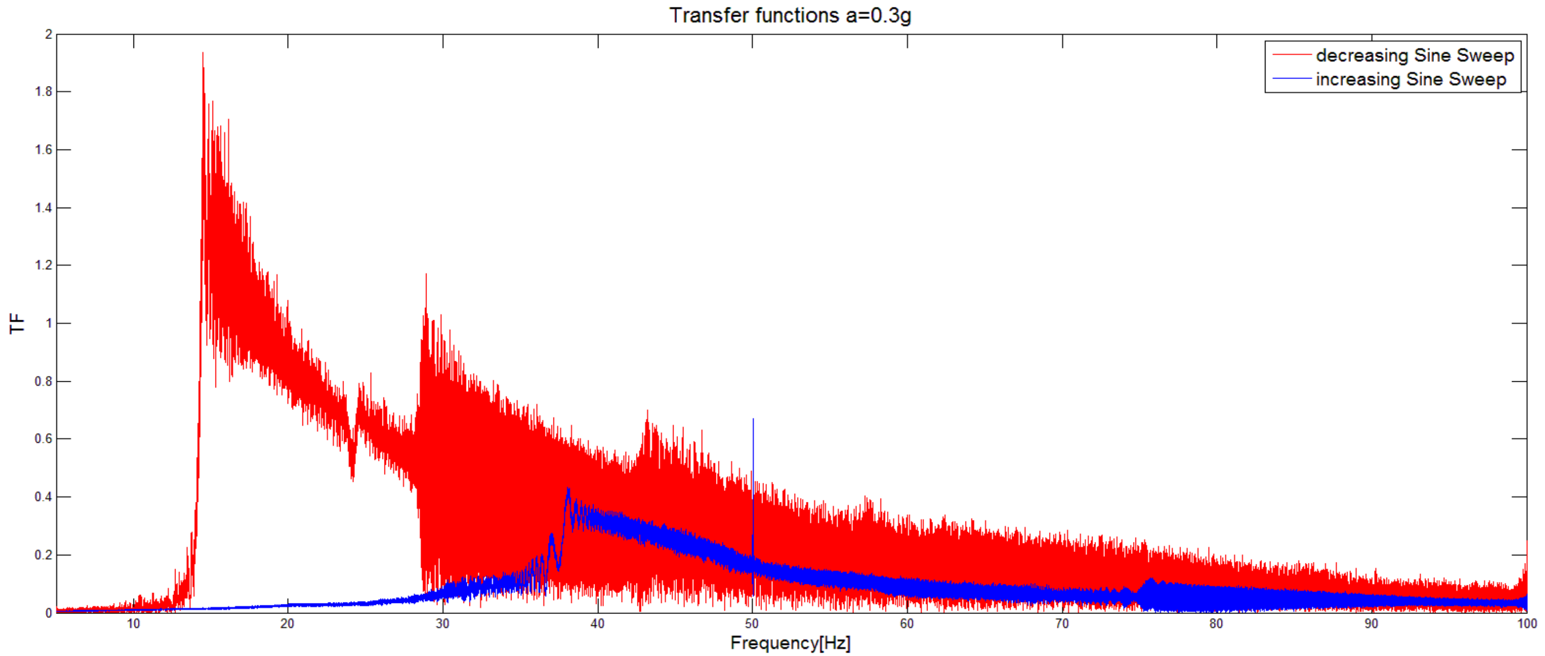
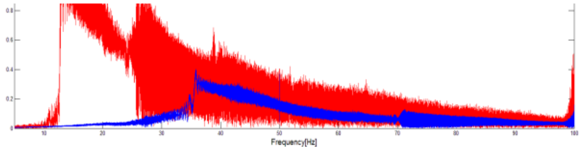
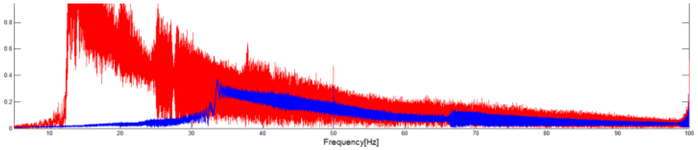
Nonlinearity through TF: hysteresis











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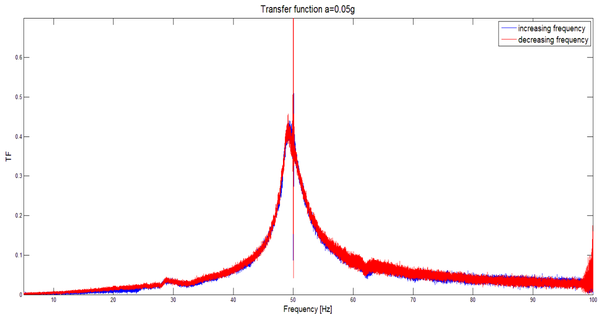
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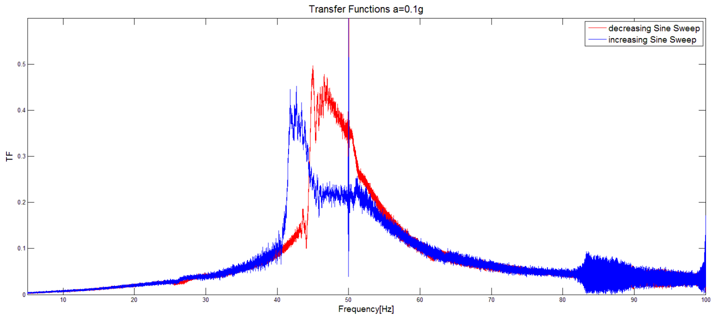
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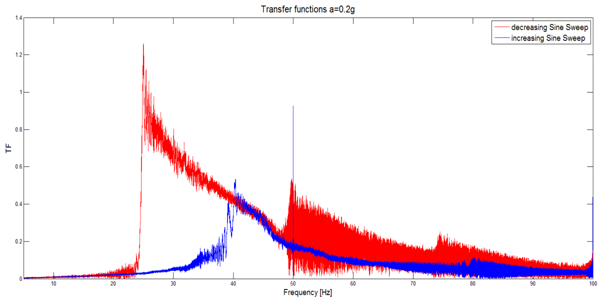
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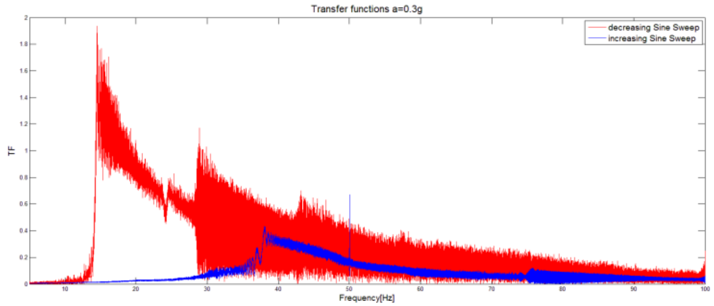
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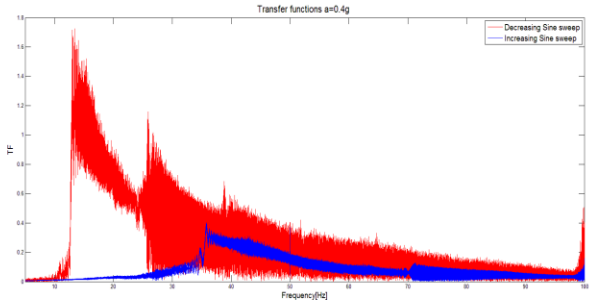
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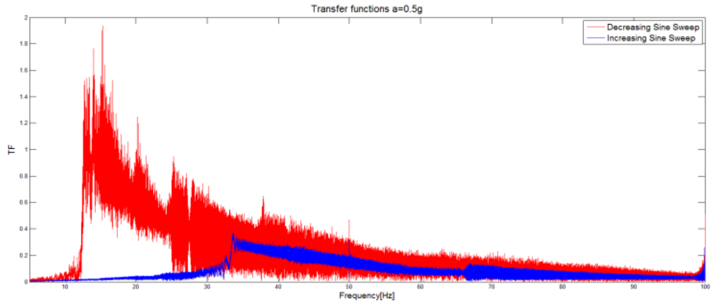
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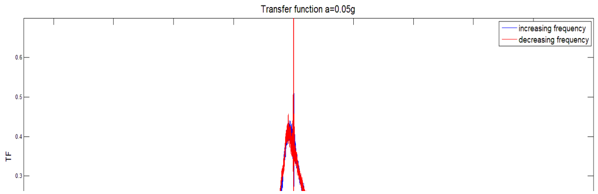
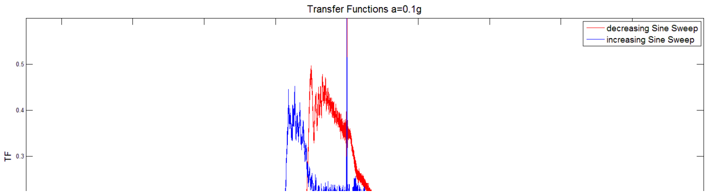
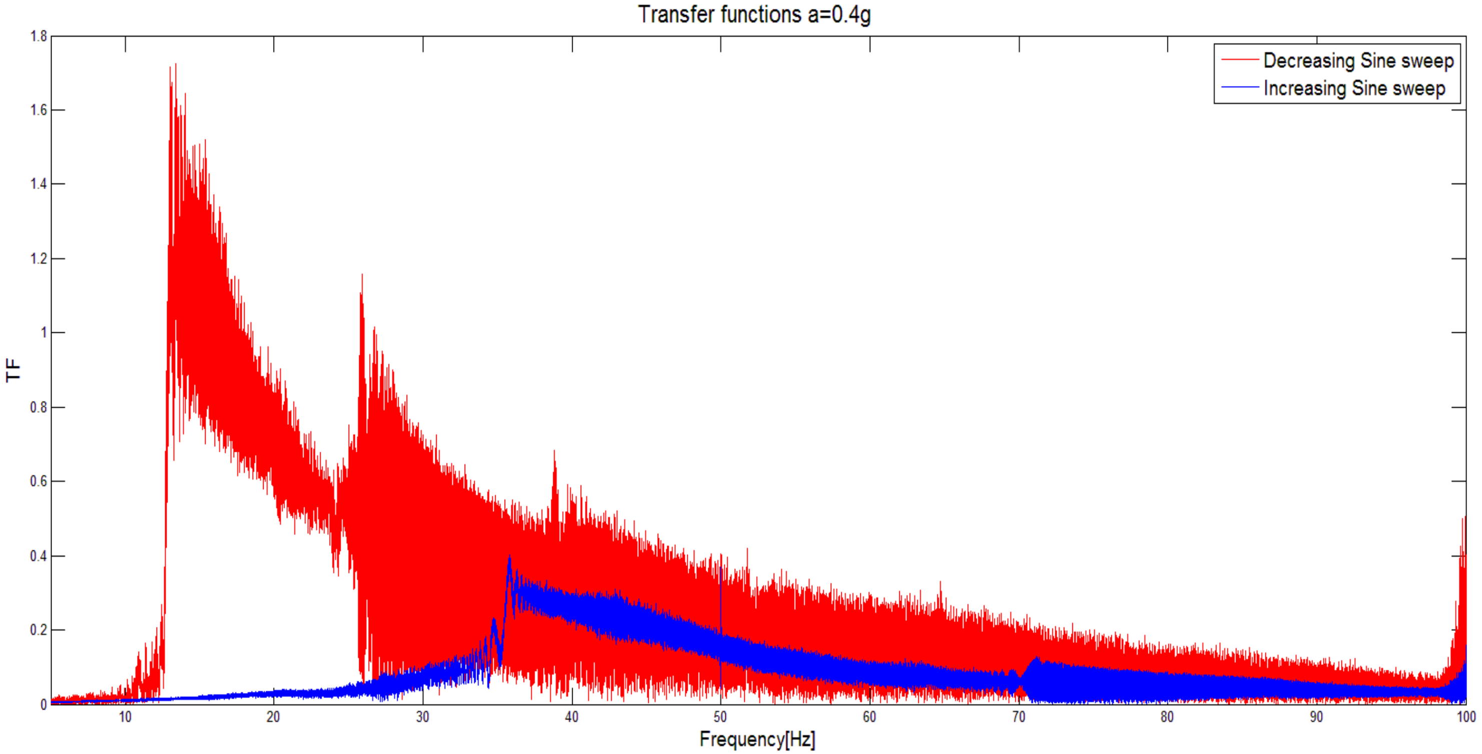
Nonlinearity through TF: hysteresis







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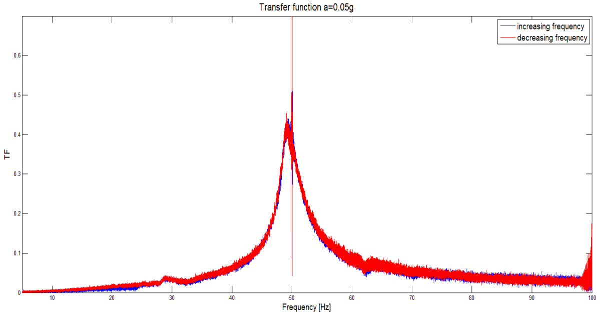

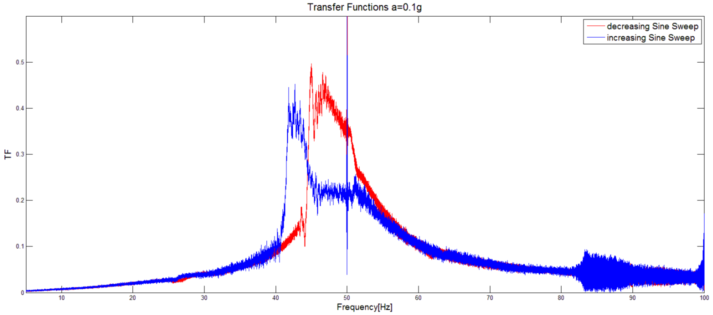

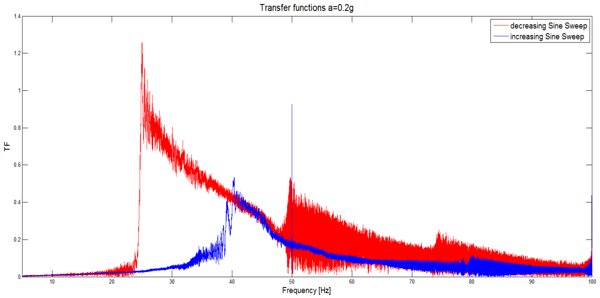

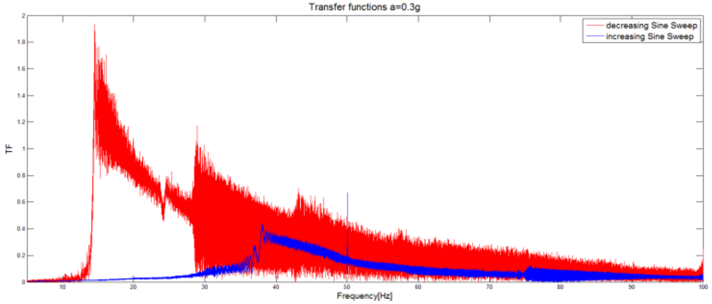

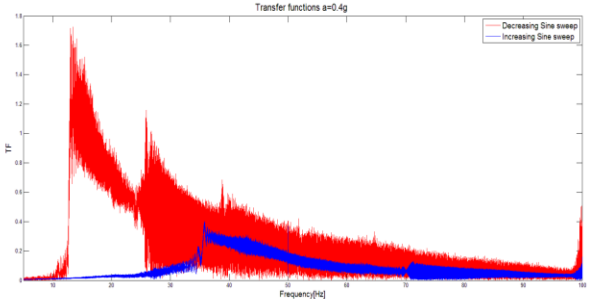

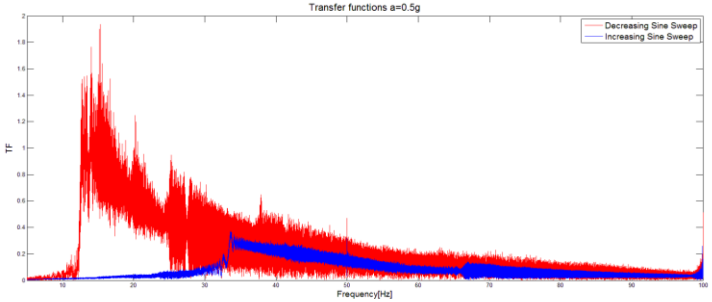

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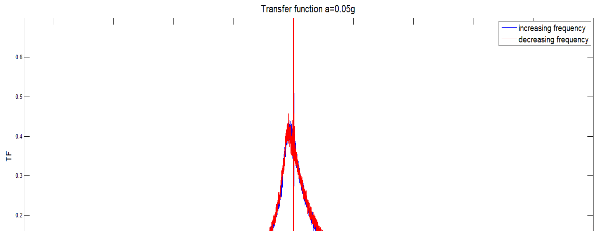
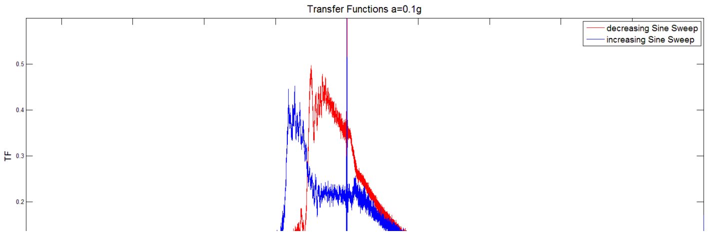
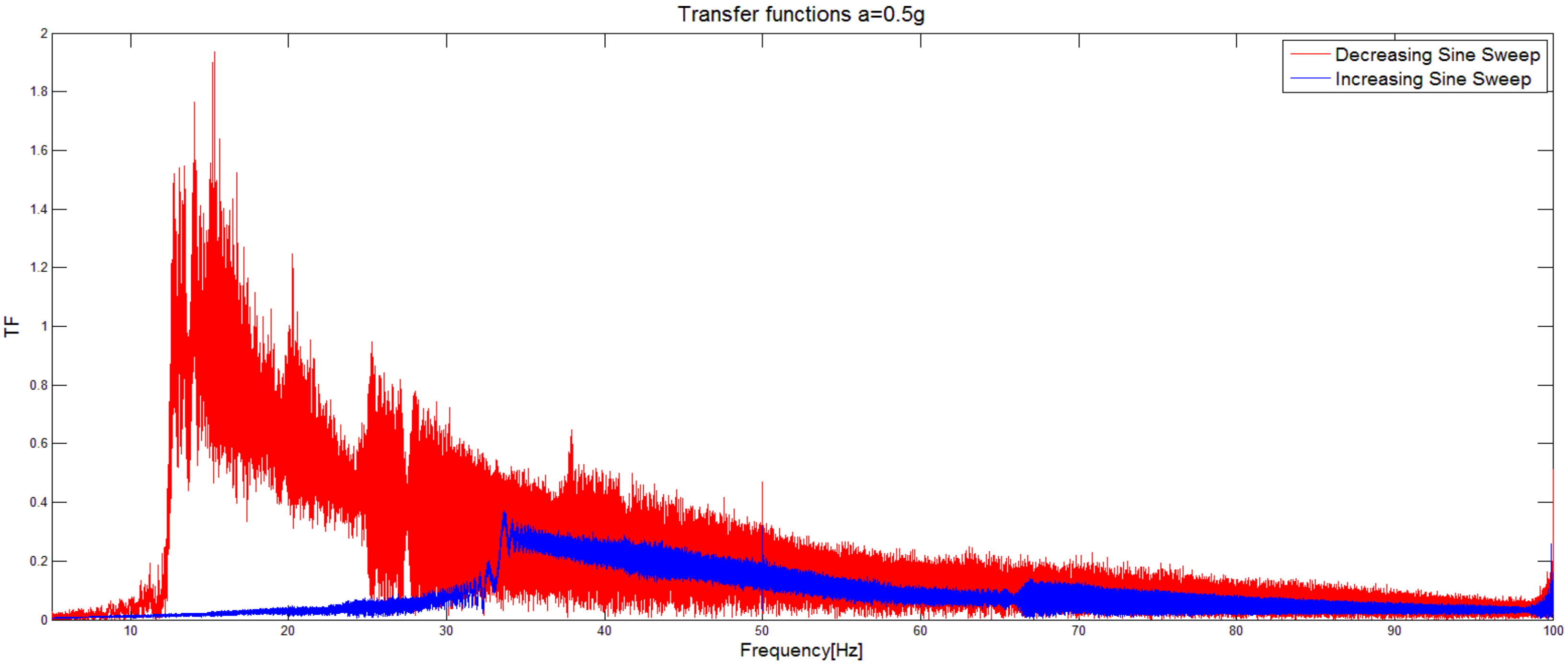
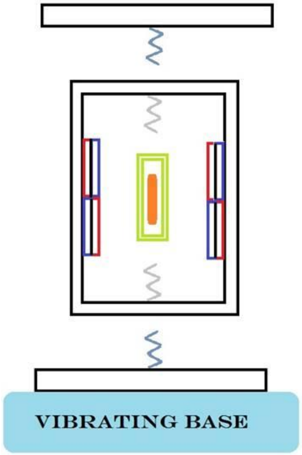
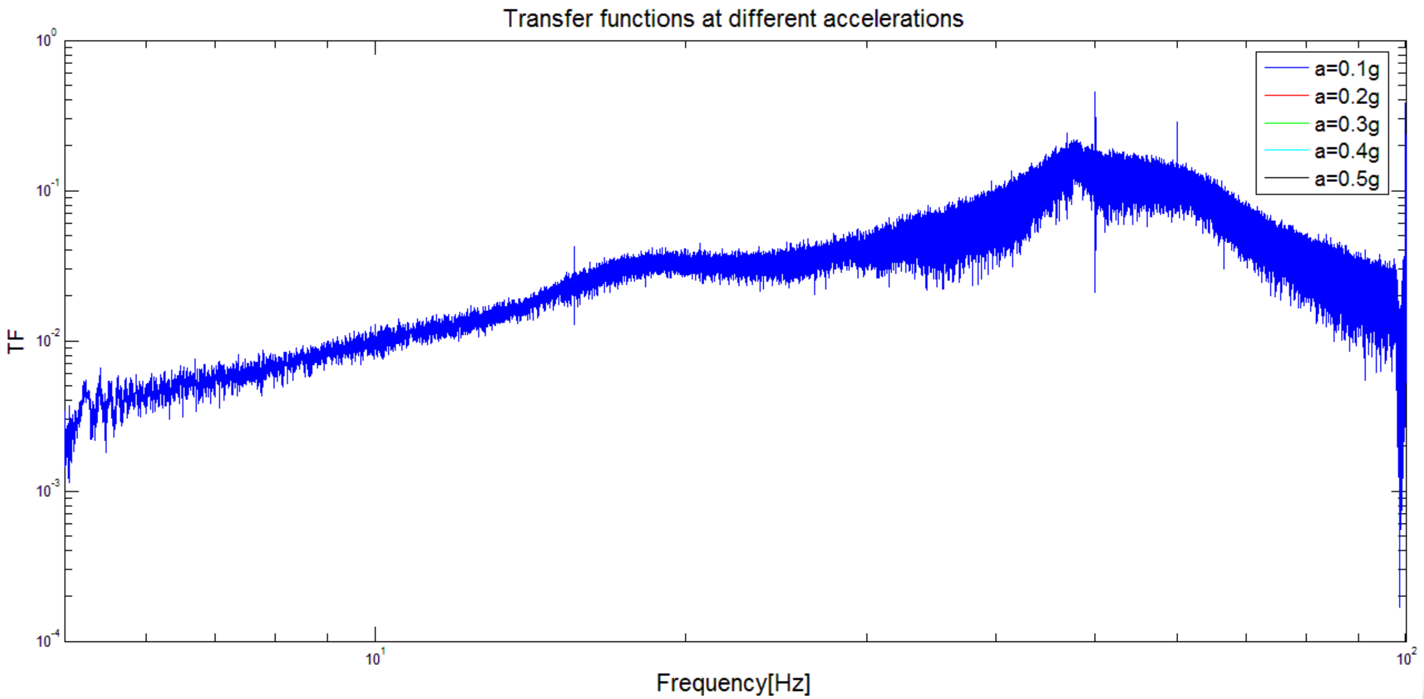




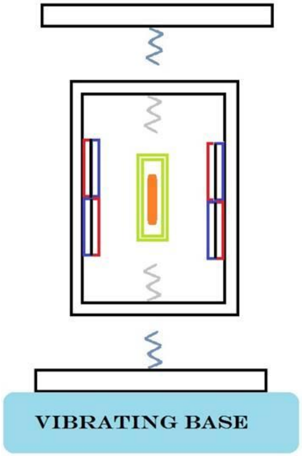


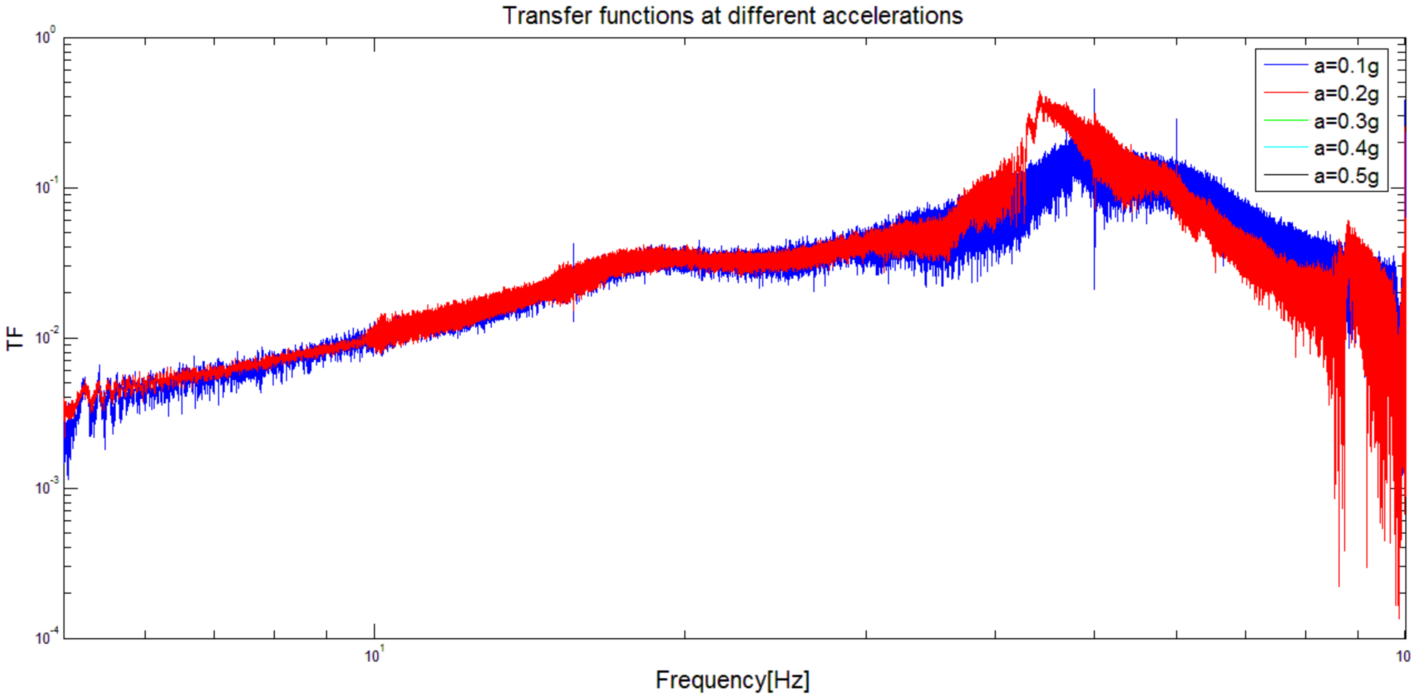
Characterization of the whole system: TFs



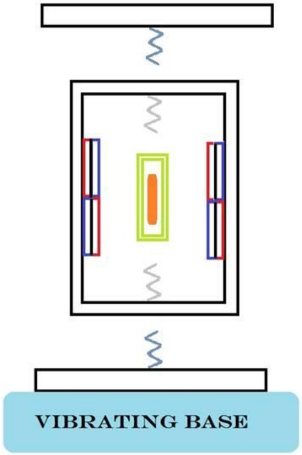

Transfer functions at different accelerations

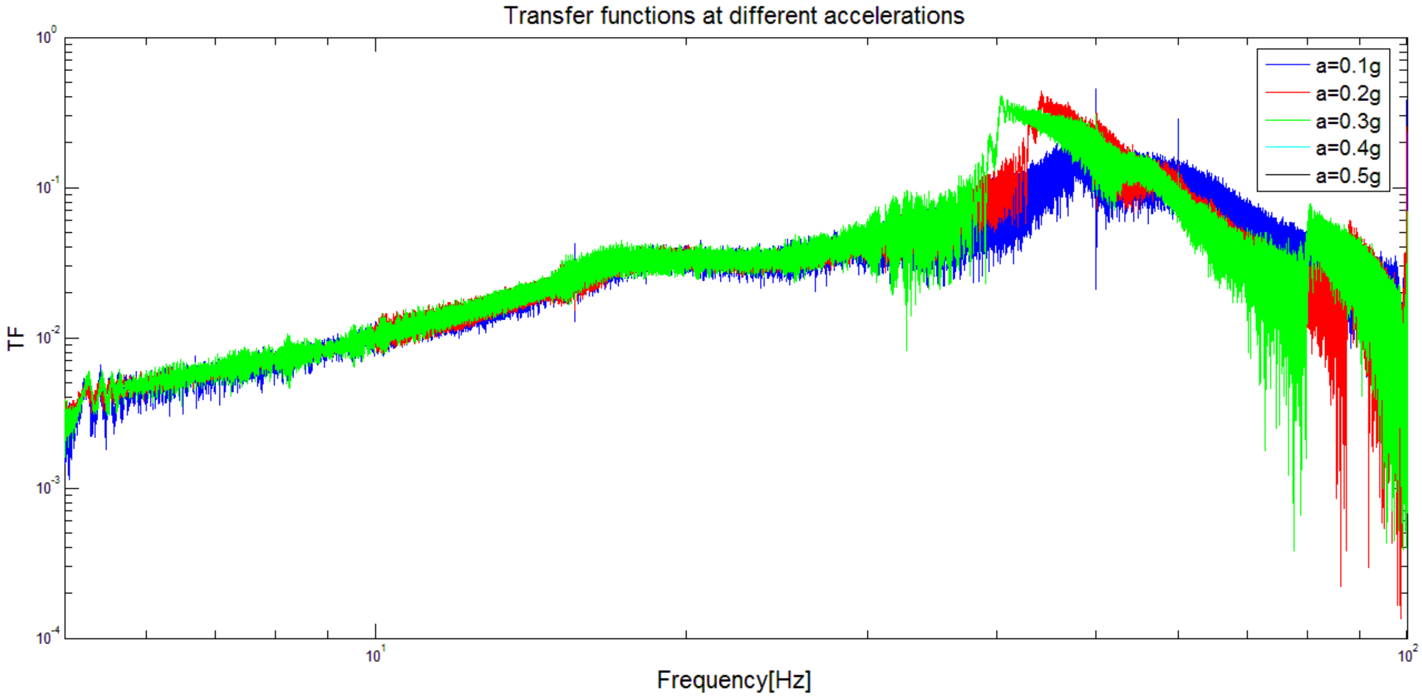
Characterization of the whole system: TFs



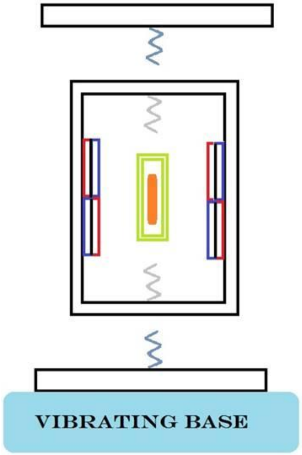


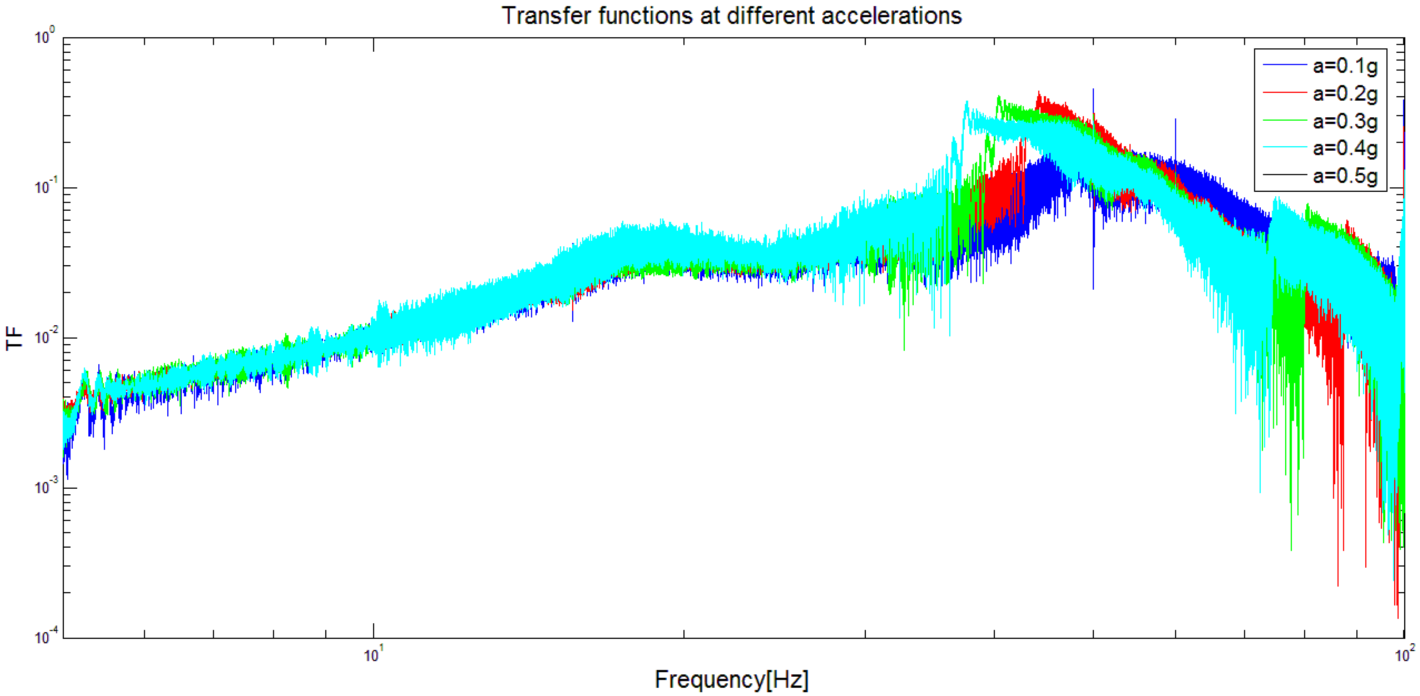
Characterization of the whole system: TFs



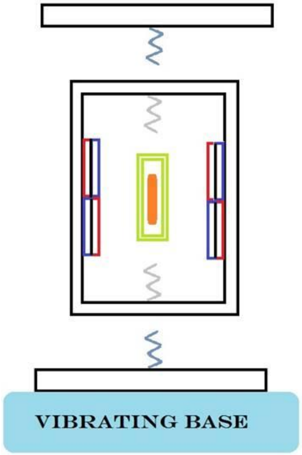


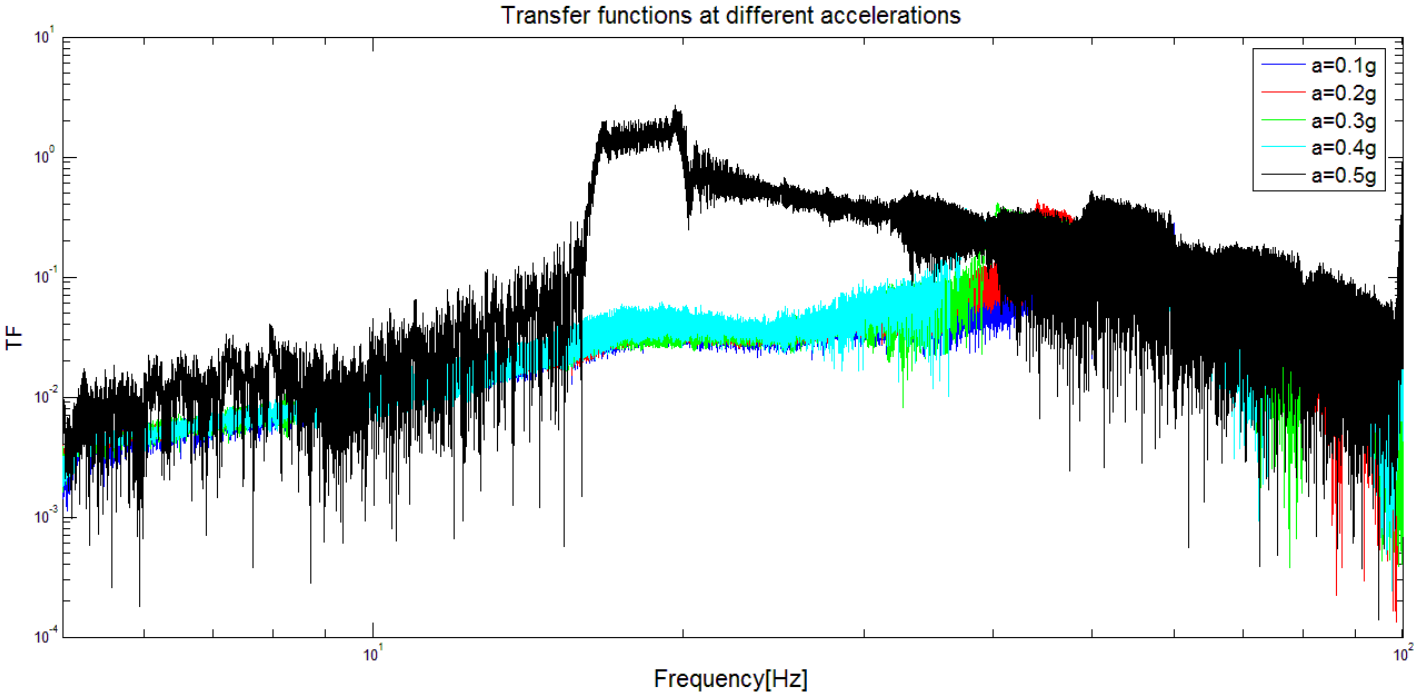
Characterization of the whole system: TFs



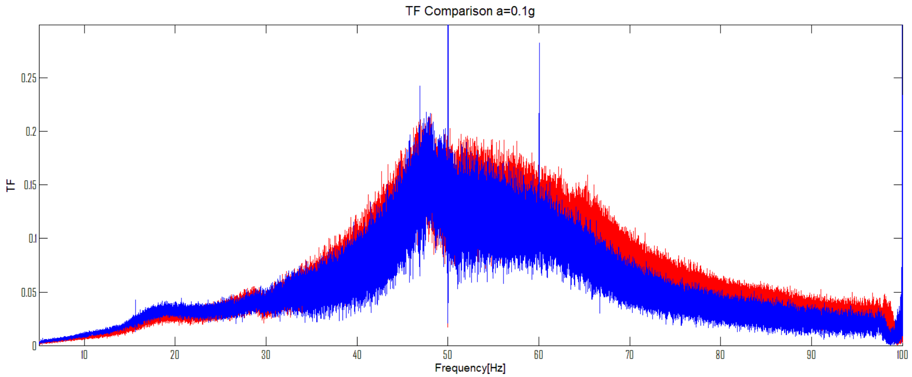


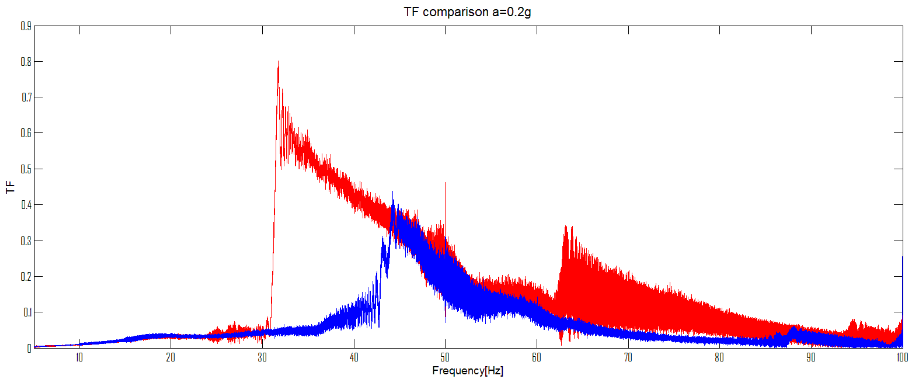
Characterization of the whole system: TFs

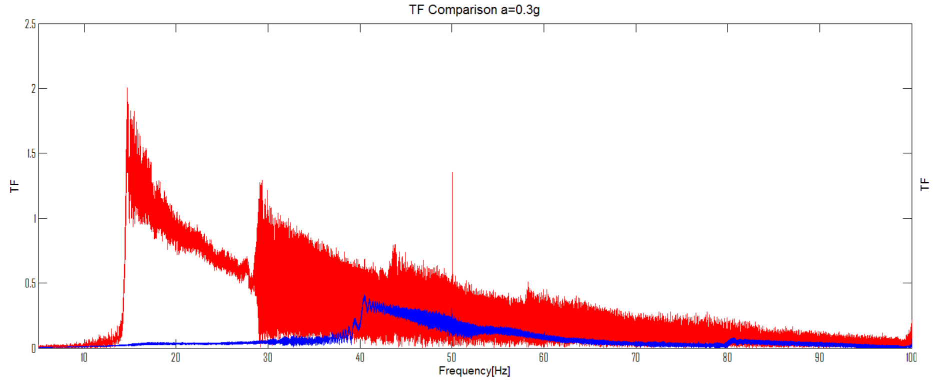


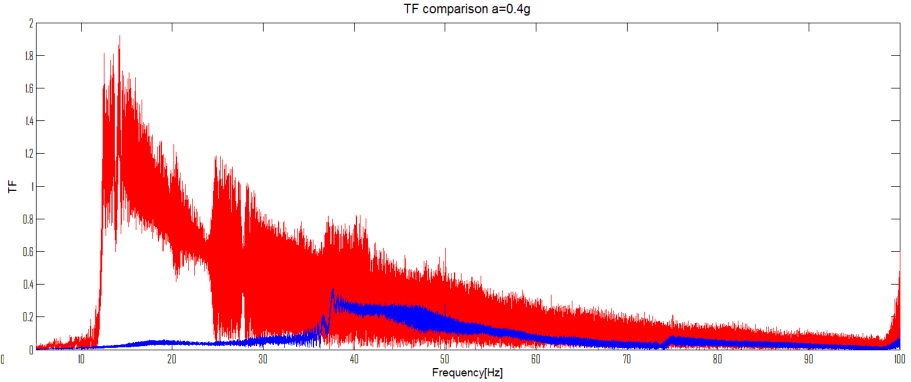


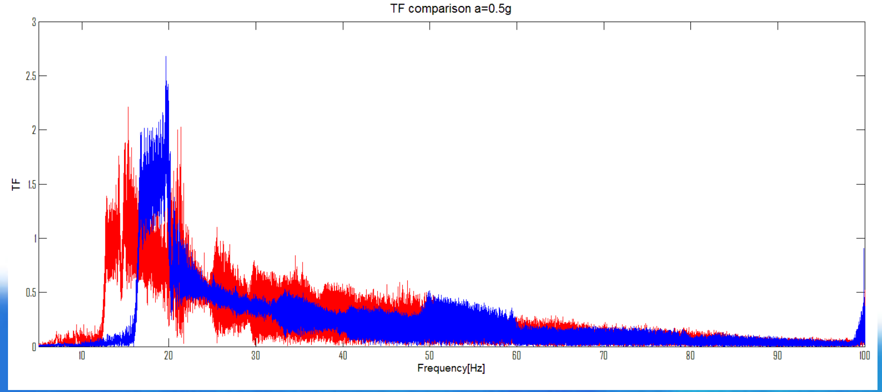
Hysteresis











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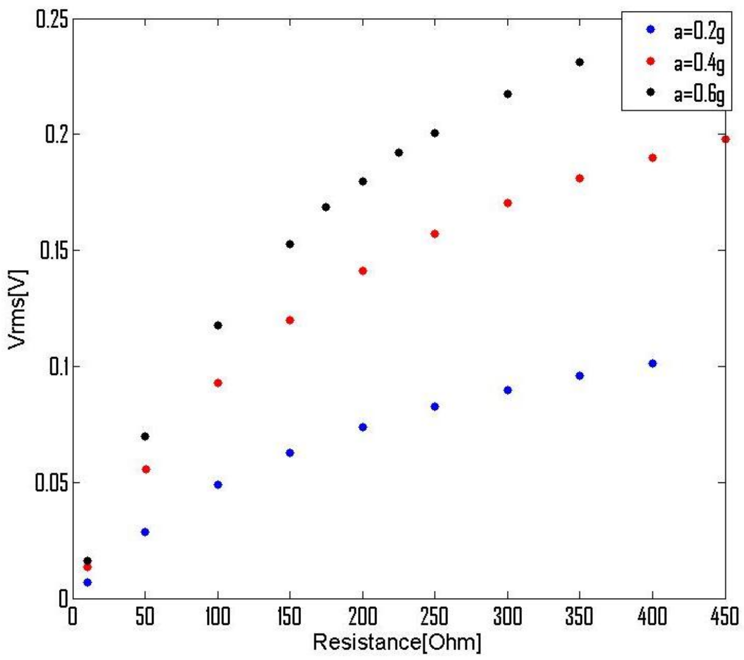
Optimization process

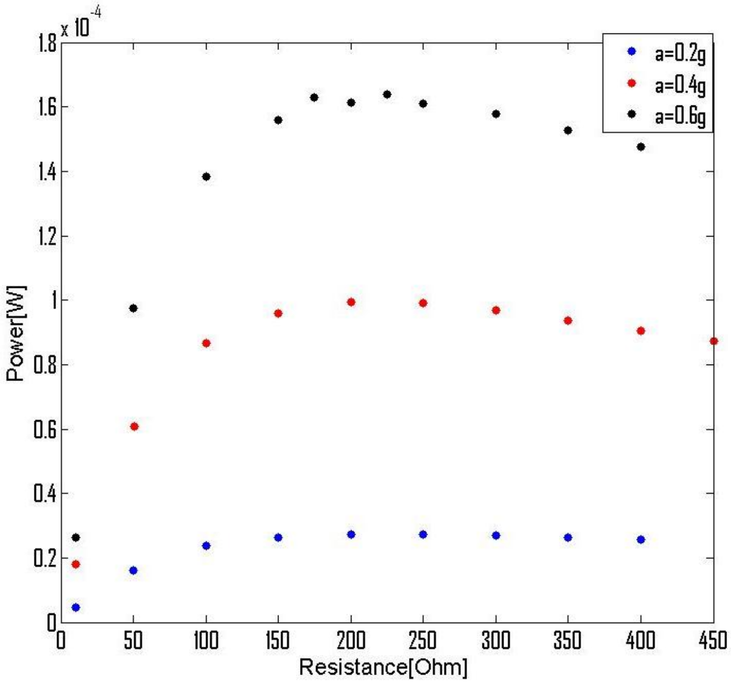
- Magnets 1/2 x 1/2 x 1/8 inches
- Coils of fixed volume r=9mm h=8mm
  - Wire diameter d=280um
  - Wire diameter d=170um
  - Wire diameter d=100um

- Outer mass steady
- For each coil the optimal resistance load has been found
- Comparison between output voltage and power for different coils at the same amplitude acceleration input

Load Resistance

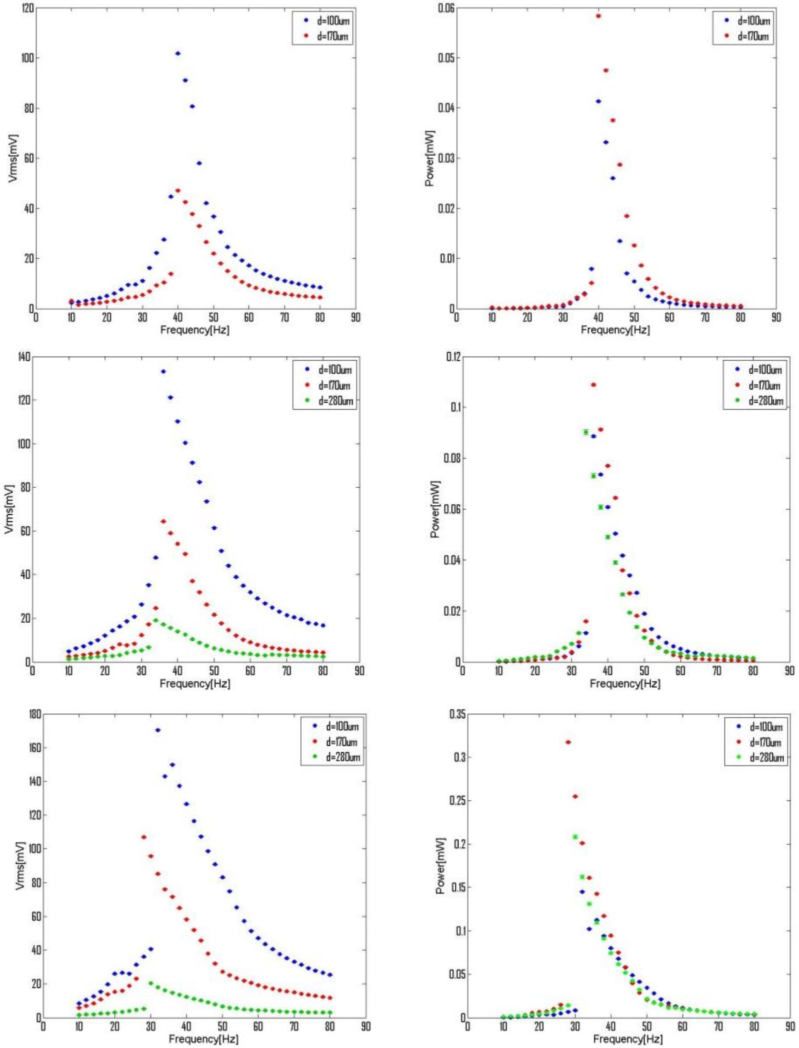
Wire d=100um





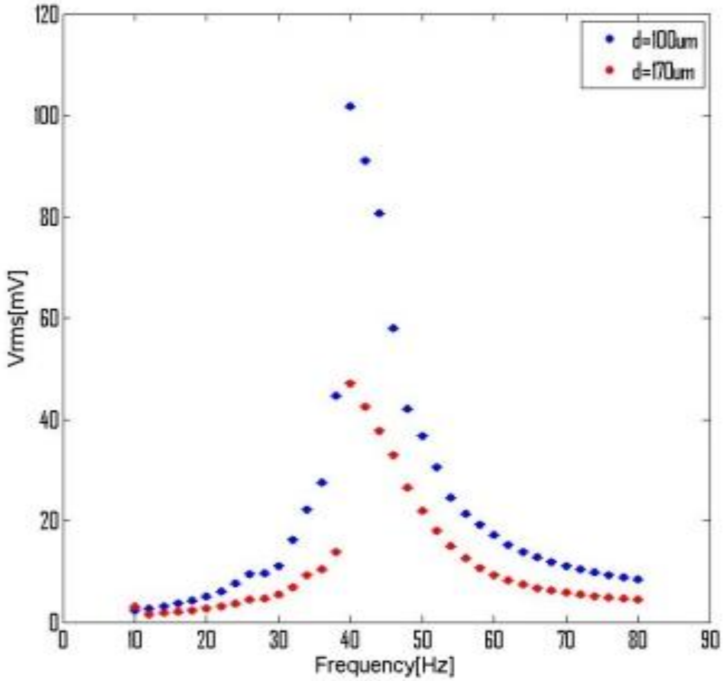
Same analysis for each coil

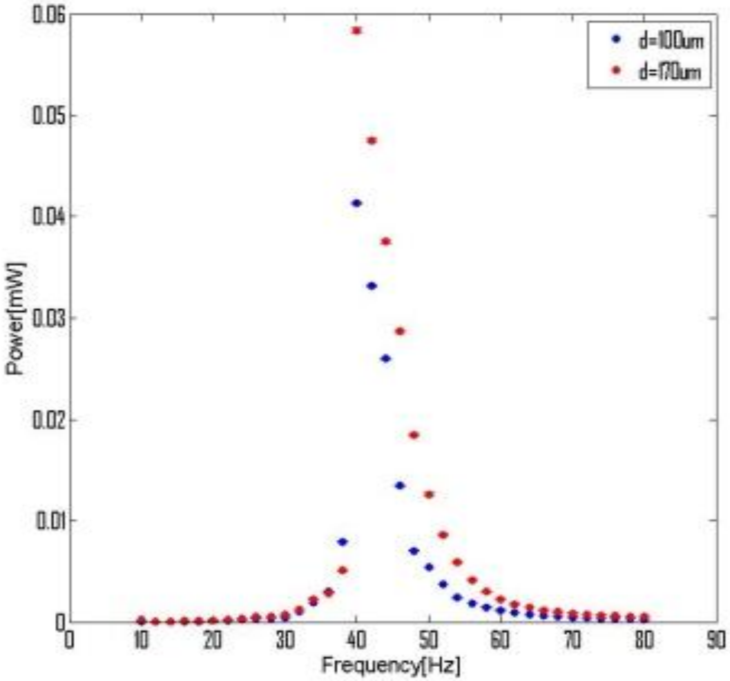
Power Optimization

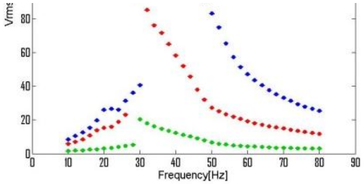


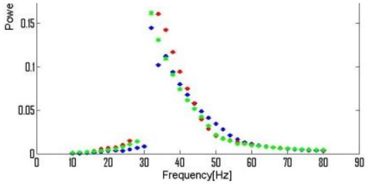
Power Optimization

Acceleration a=0.2g

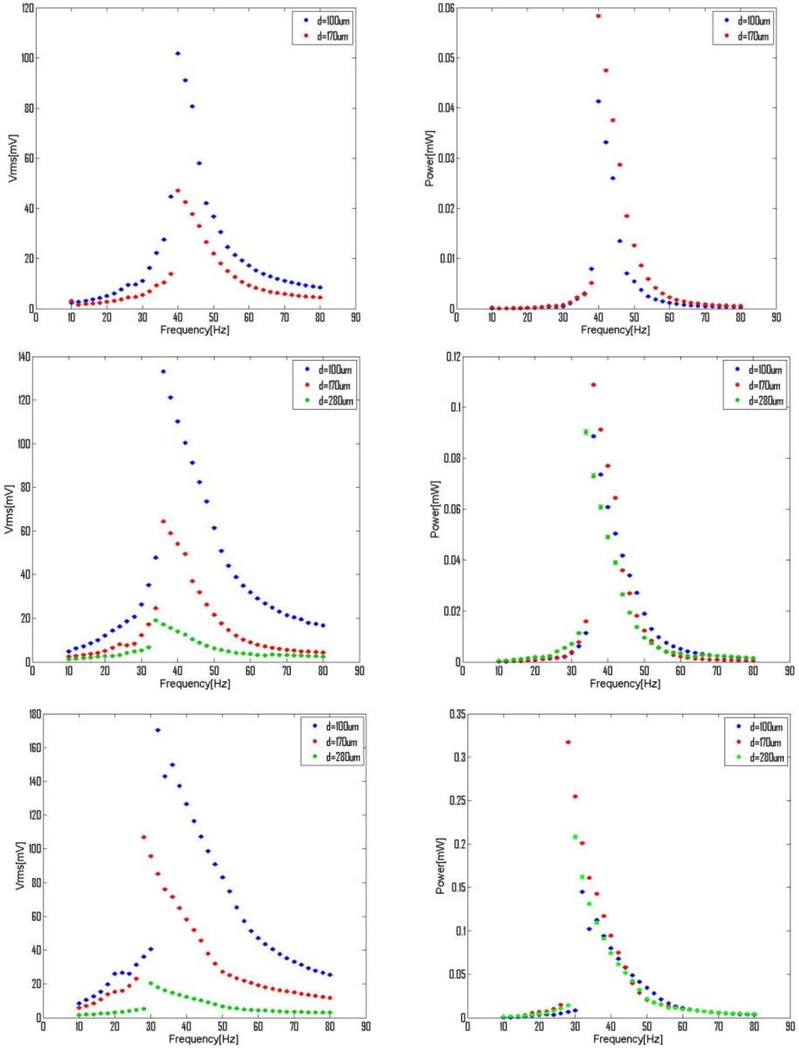




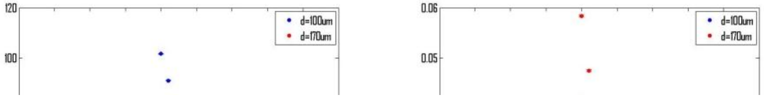




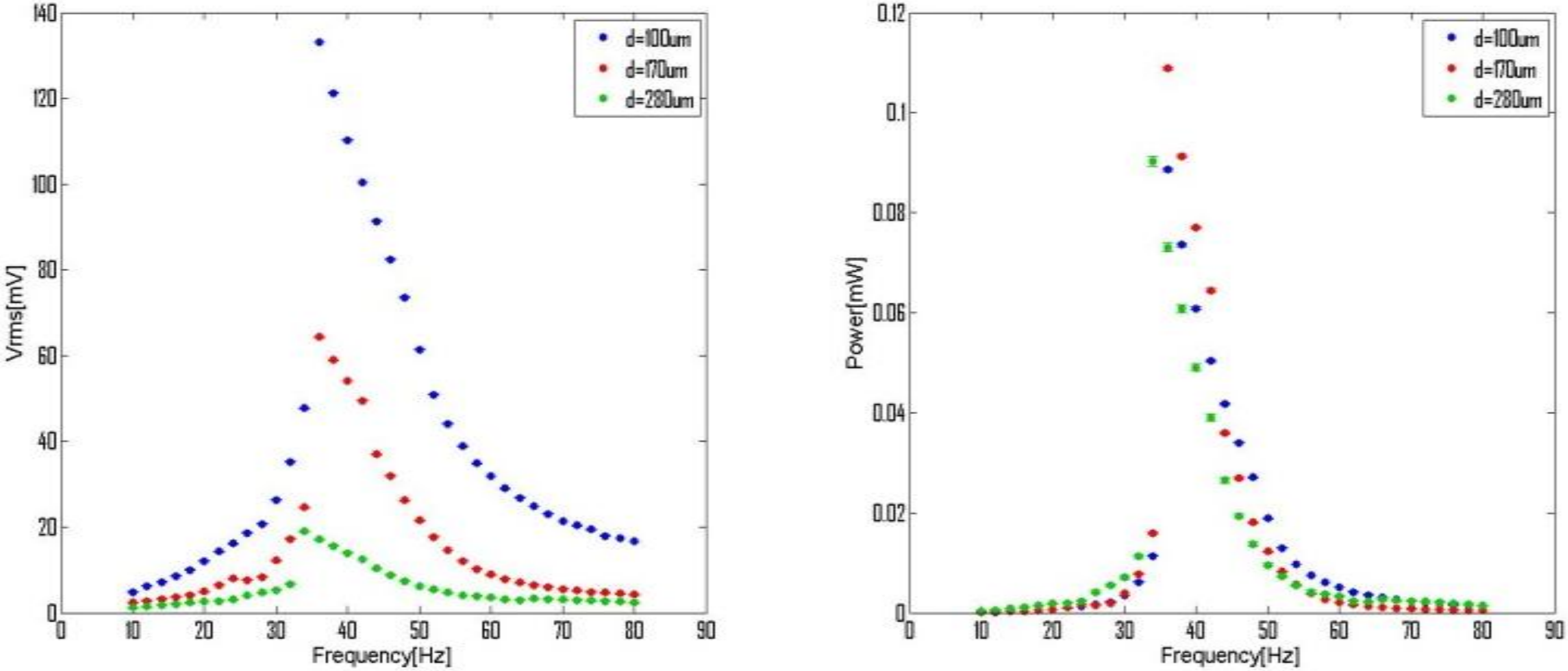
Power Optimization

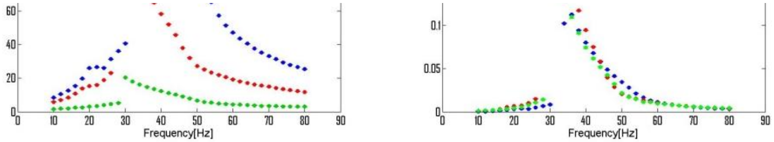


Power Optimization

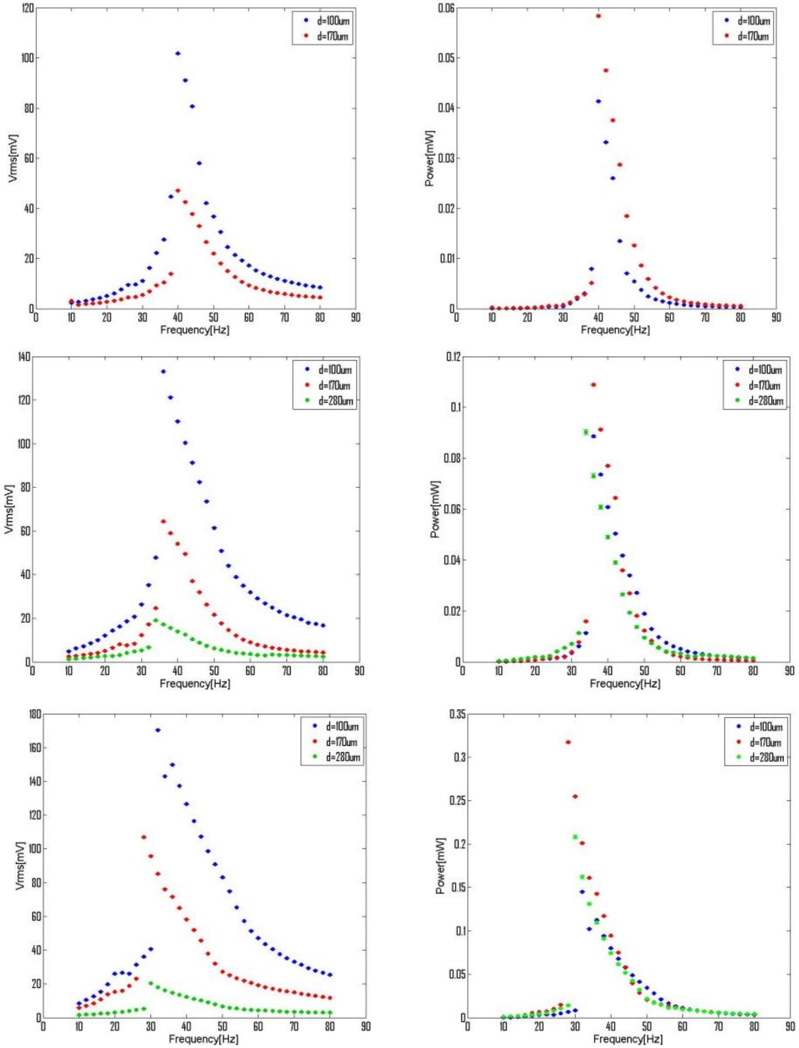


Acceleration a=0.4g

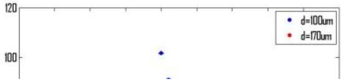


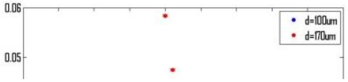


Power Optimization

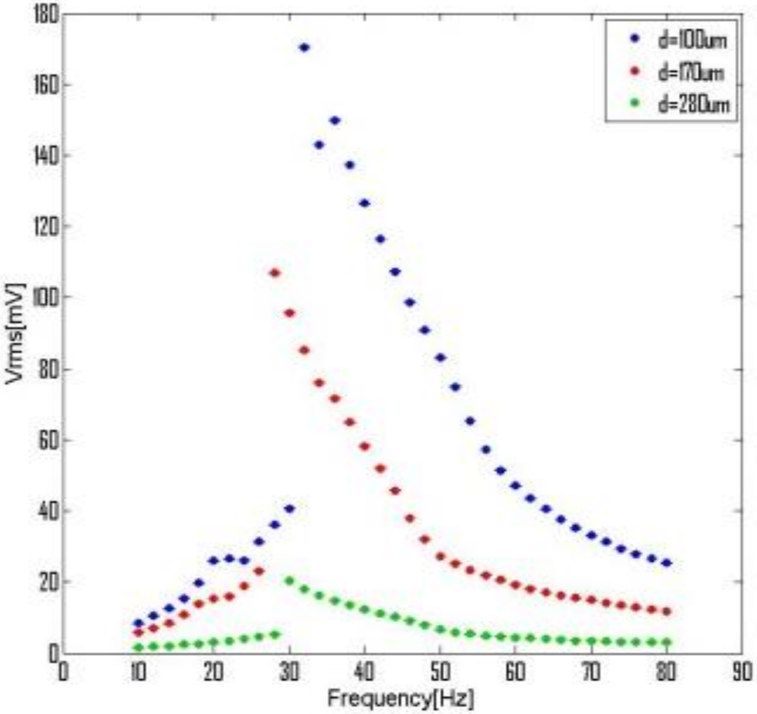


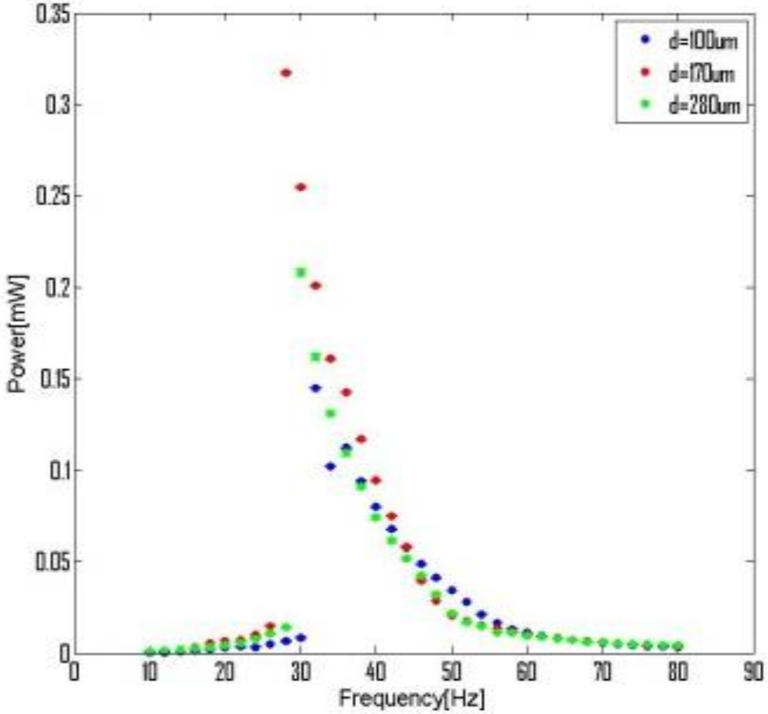
Power Optimization

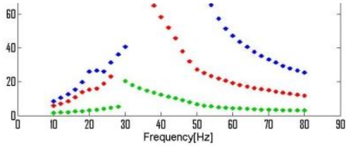


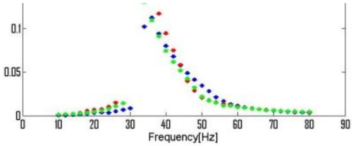


Acceleration a=0.6g









Conclusions and Wish List

- ✓ Study and interpretation of the TFs:
  - ✓ At very little acceleration the system in basically linear, but early it becomes (also for the little mass alone) nonlinear
  - ✓ We can think about miniaturize this system even if the linear resonance frequency increases, using the nonlinear shifting
- ✓ The coil with the 170um diameter wire seems to be the best for maximizing the power output with this set of magnets

- ➢ Find the best configuration for the magnets
- ➢ Miniaturization

Thank you for your attention....
Questions?

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