Vibration powered wireless sensor and performance comparison

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NANOPOWER

NiPS Laboratory
Noise in Physical Systems

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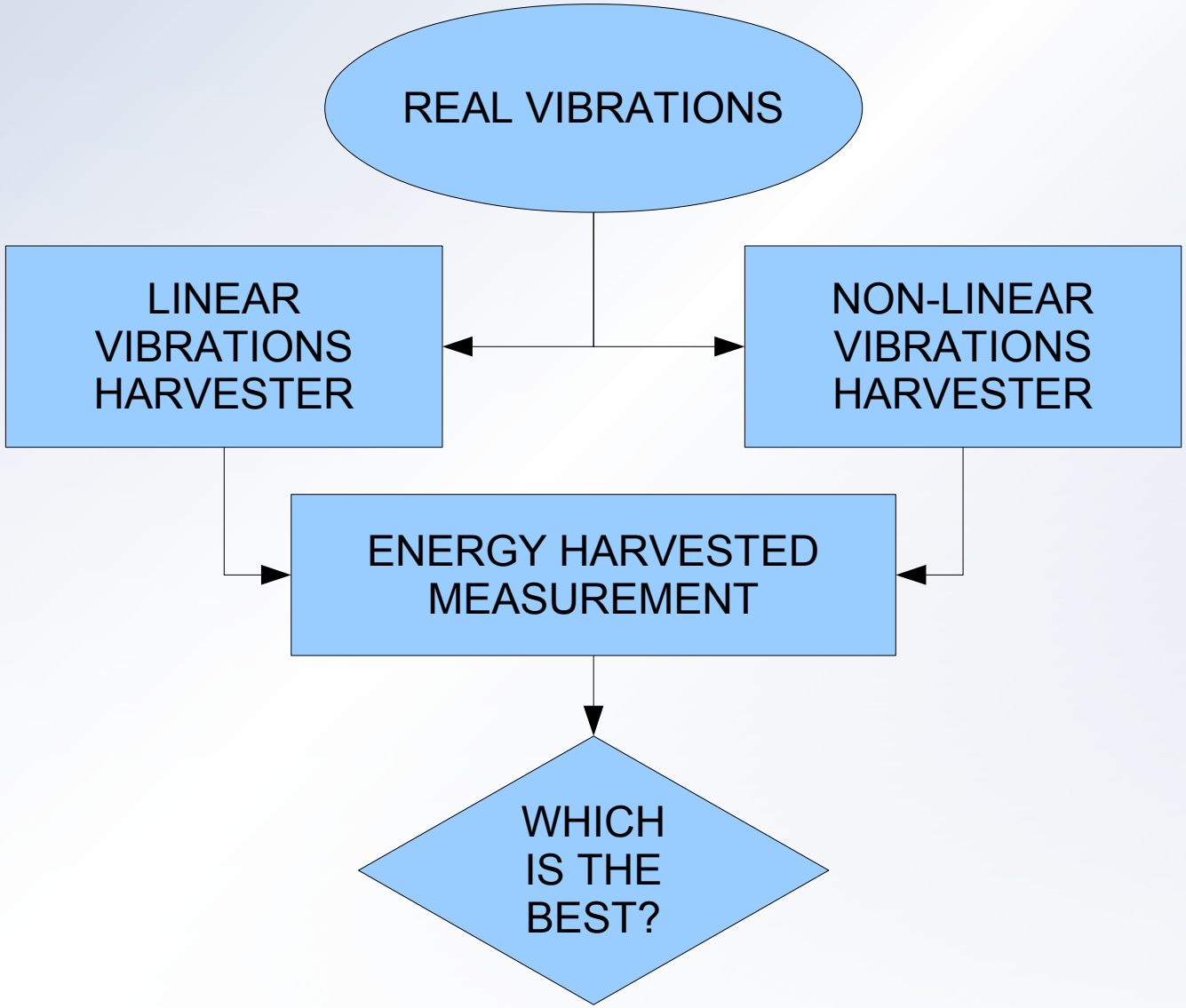
Outline

- Aim of the presentation
- Vibration database – signals for the tests
- Overview of the test system
- Test setup
- Test procedure
- Preliminary tests on the piezoelectric harvester
- Linear mode vs non-linear mode tests
- A practical example
- A real application
- Conclusions

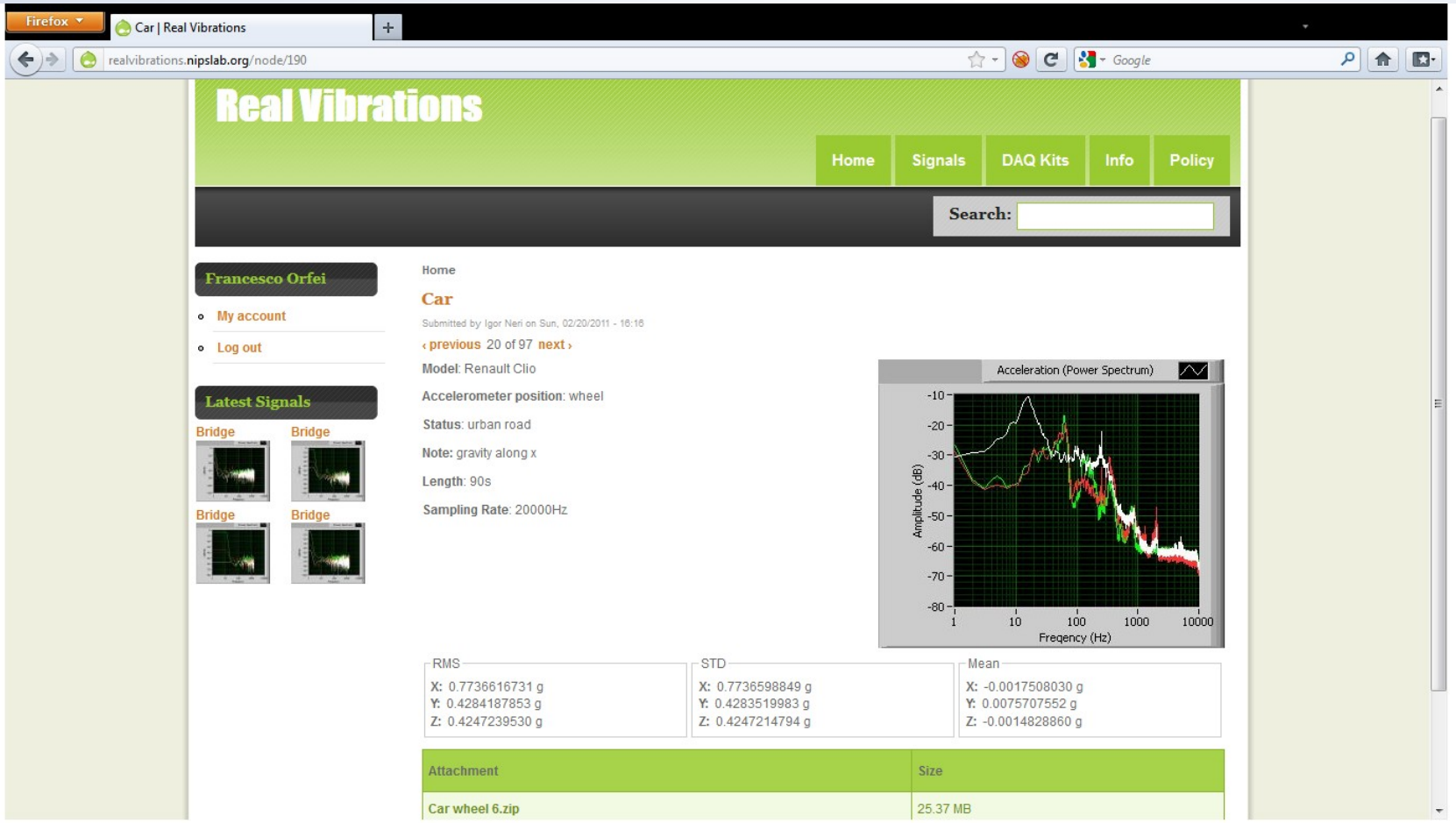
Aim of the presentation



Vibration database – signals for the tests

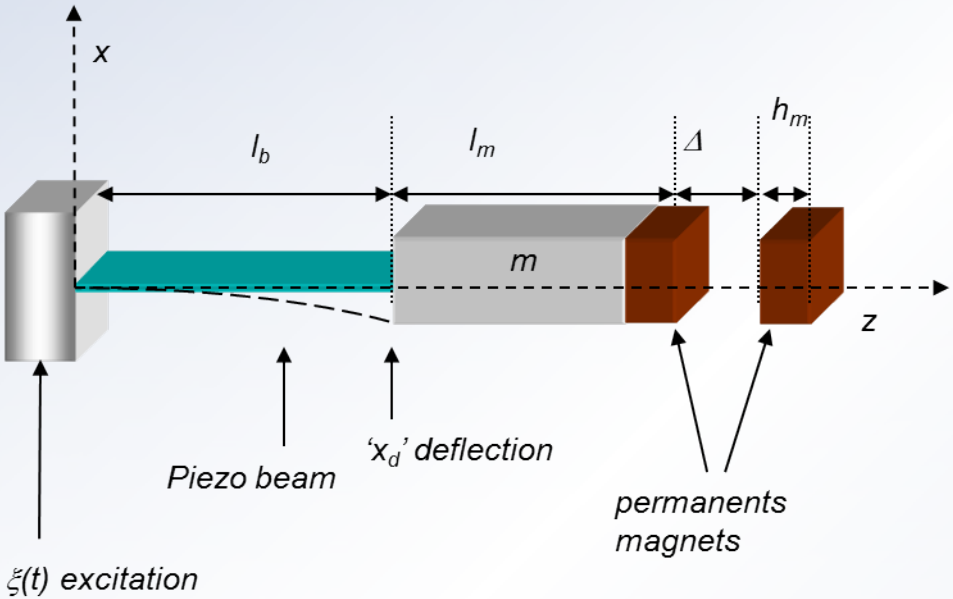
VIBRATIONS DATABASE BY NiPS LAB

http://realvibrations.nipslab.org



Vibration harvester

NON-LINEAR VIBRATION HARVESTER



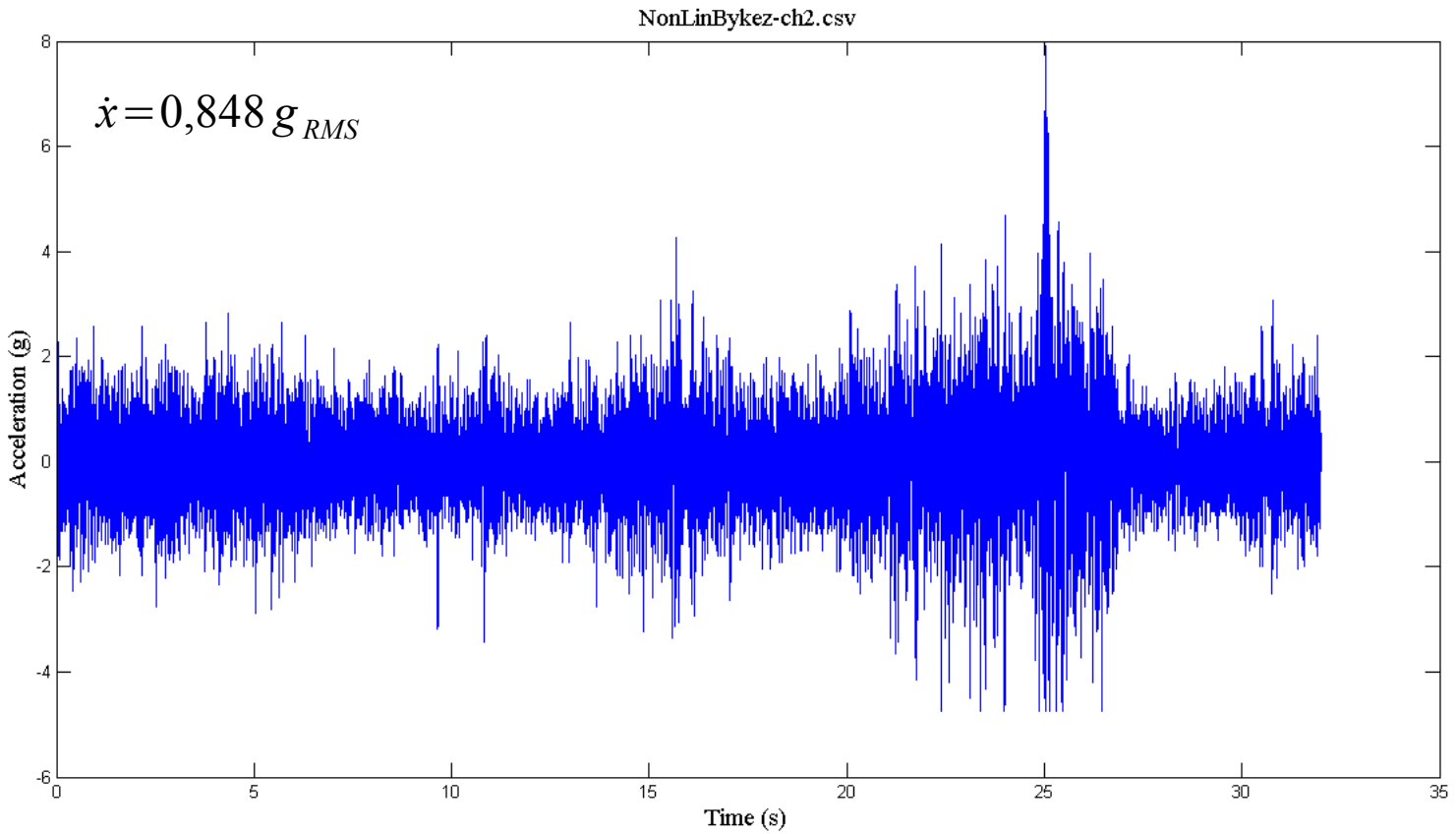
$$\ddot{x} = -\frac{dU(x)}{dx} - \gamma \dot{x} - K_v - \sigma \xi(t)$$

$$\dot{V} = -K_c \dot{x} - \frac{1}{\tau_p} V$$

L. Gammaitoni, I. Neri, and H. Vocca, APPLIED PHYSICS LETTERS 94, 164102 .2009.

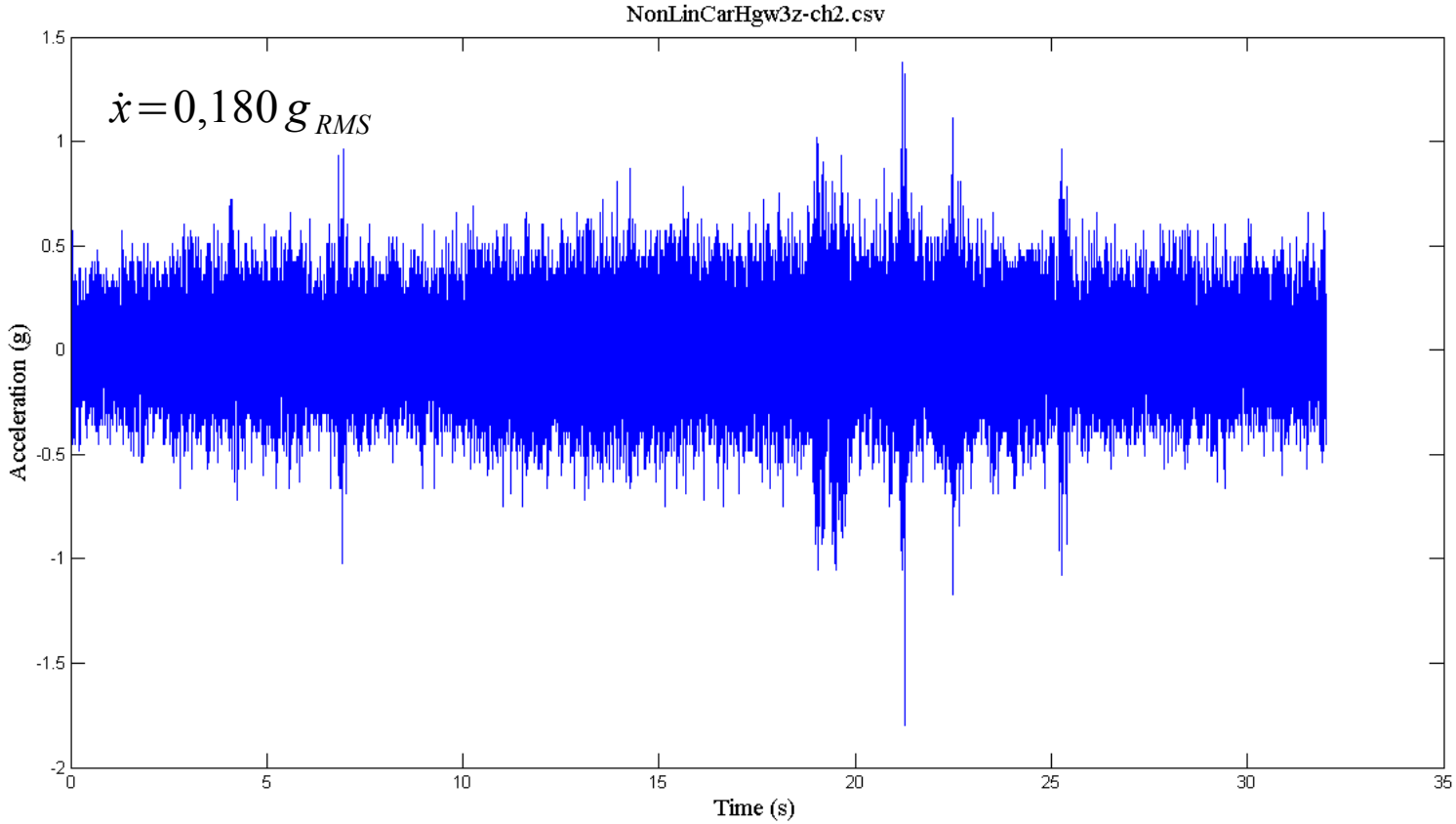
Vibration database – signals for the tests

VIBRATION TIME SERIES OF A BICYCLE



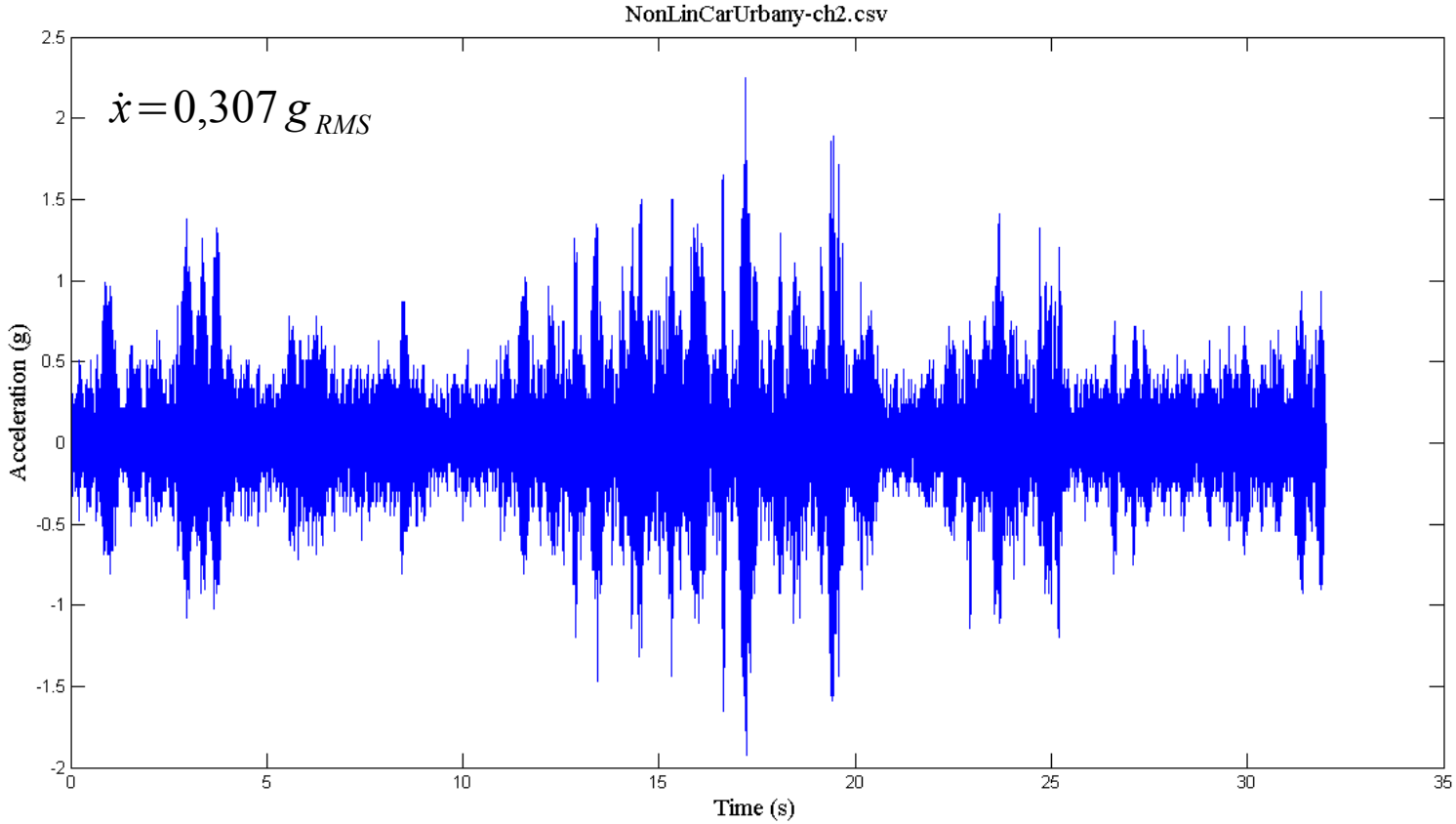
Vibration database – signals for the tests

VIBRATION TIME SERIES OF A CAR ON HIGHWAY



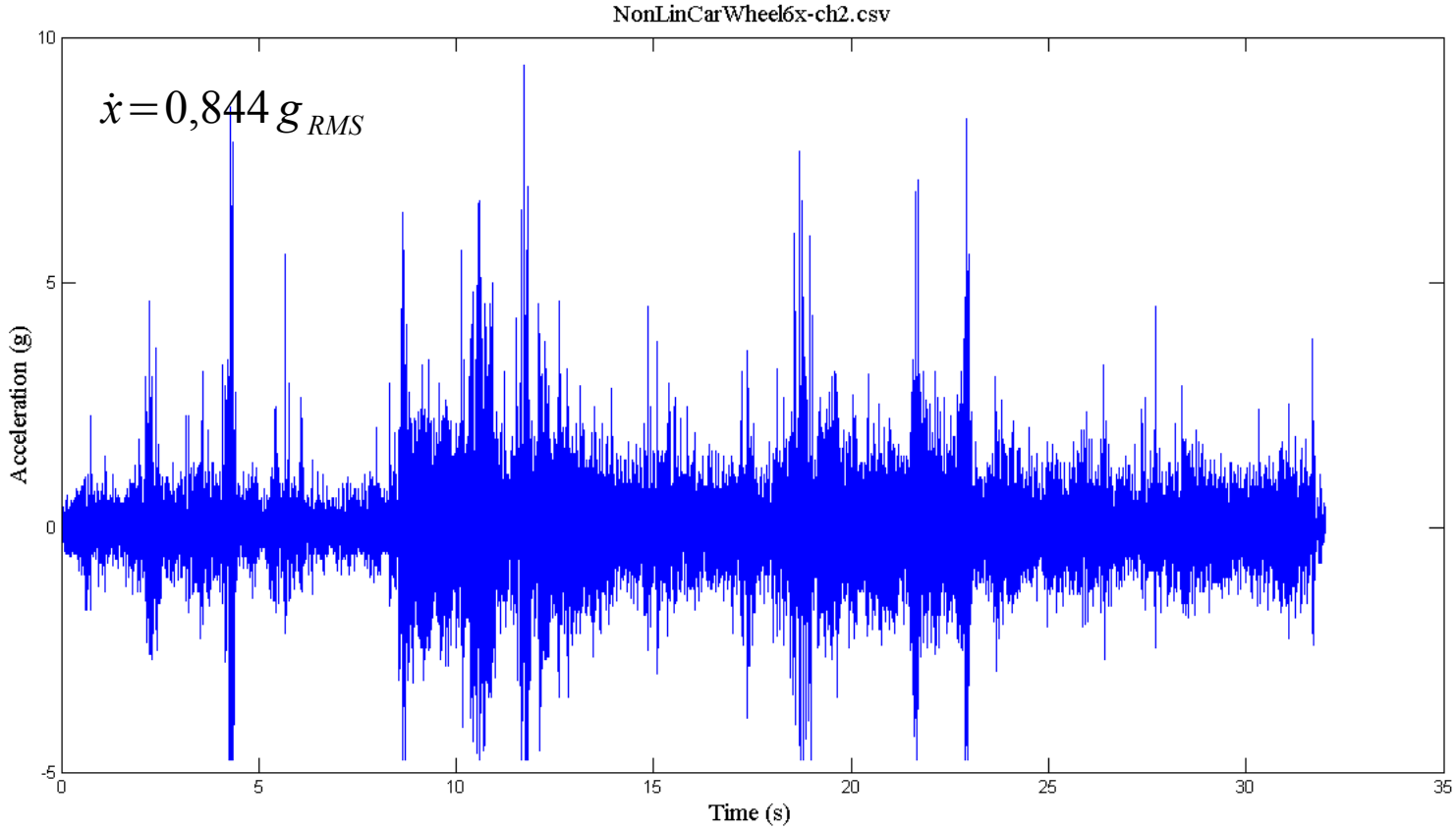
Vibration database – signals for the tests

VIBRATION TIME SERIES OF A CAR ON URBAN ROAD

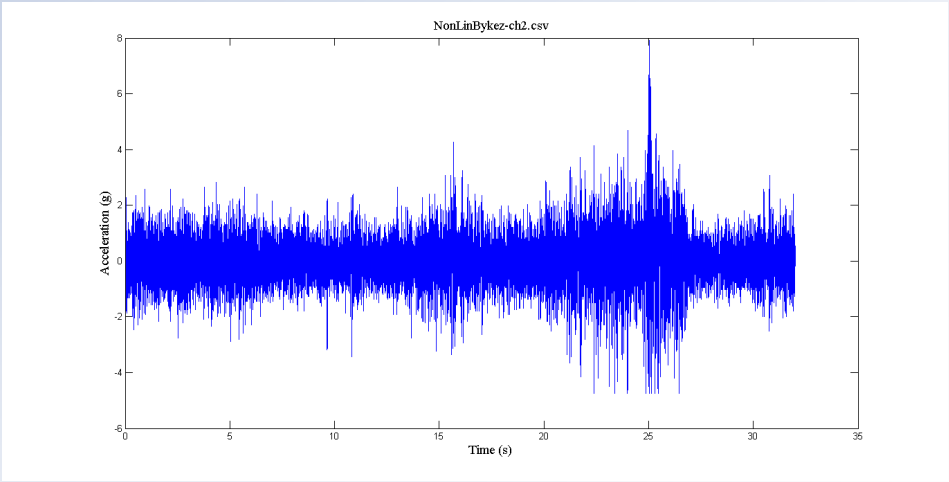


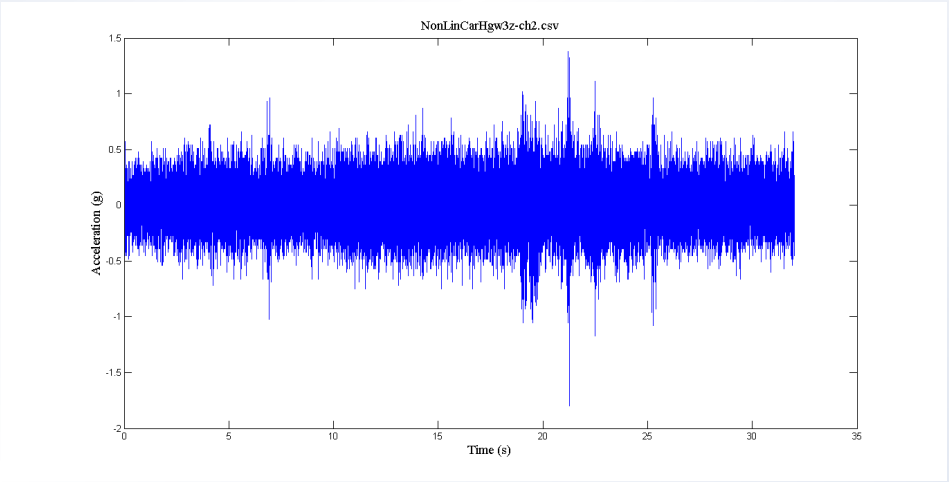
Vibration database – signals for the tests

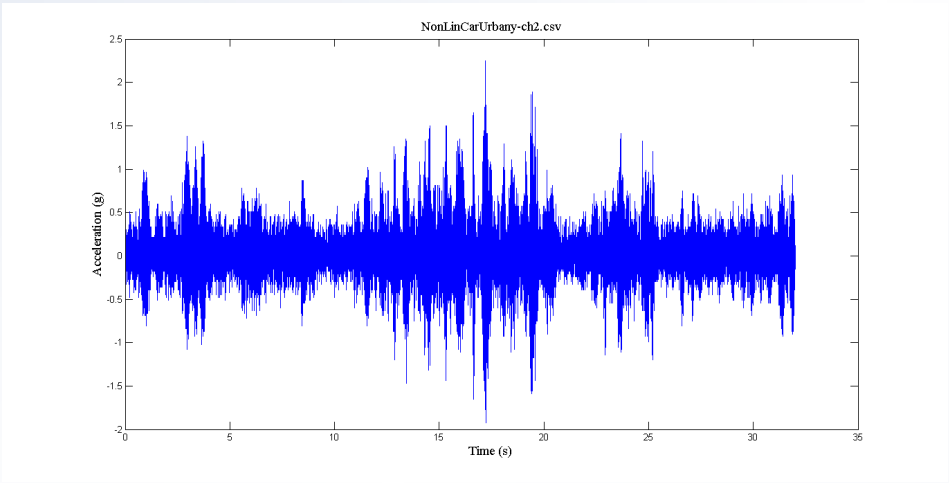
VIBRATION TIME SERIES OF A WHEEL AXLE

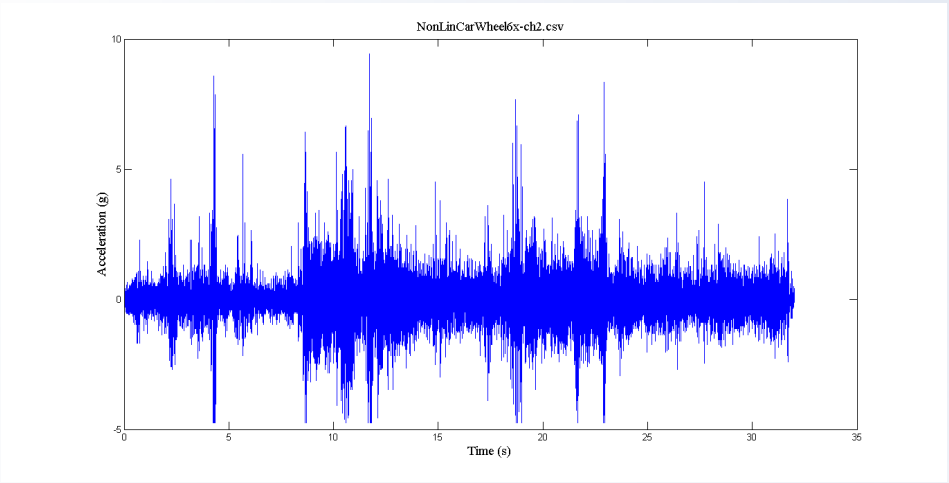


Vibration database – signals for the tests



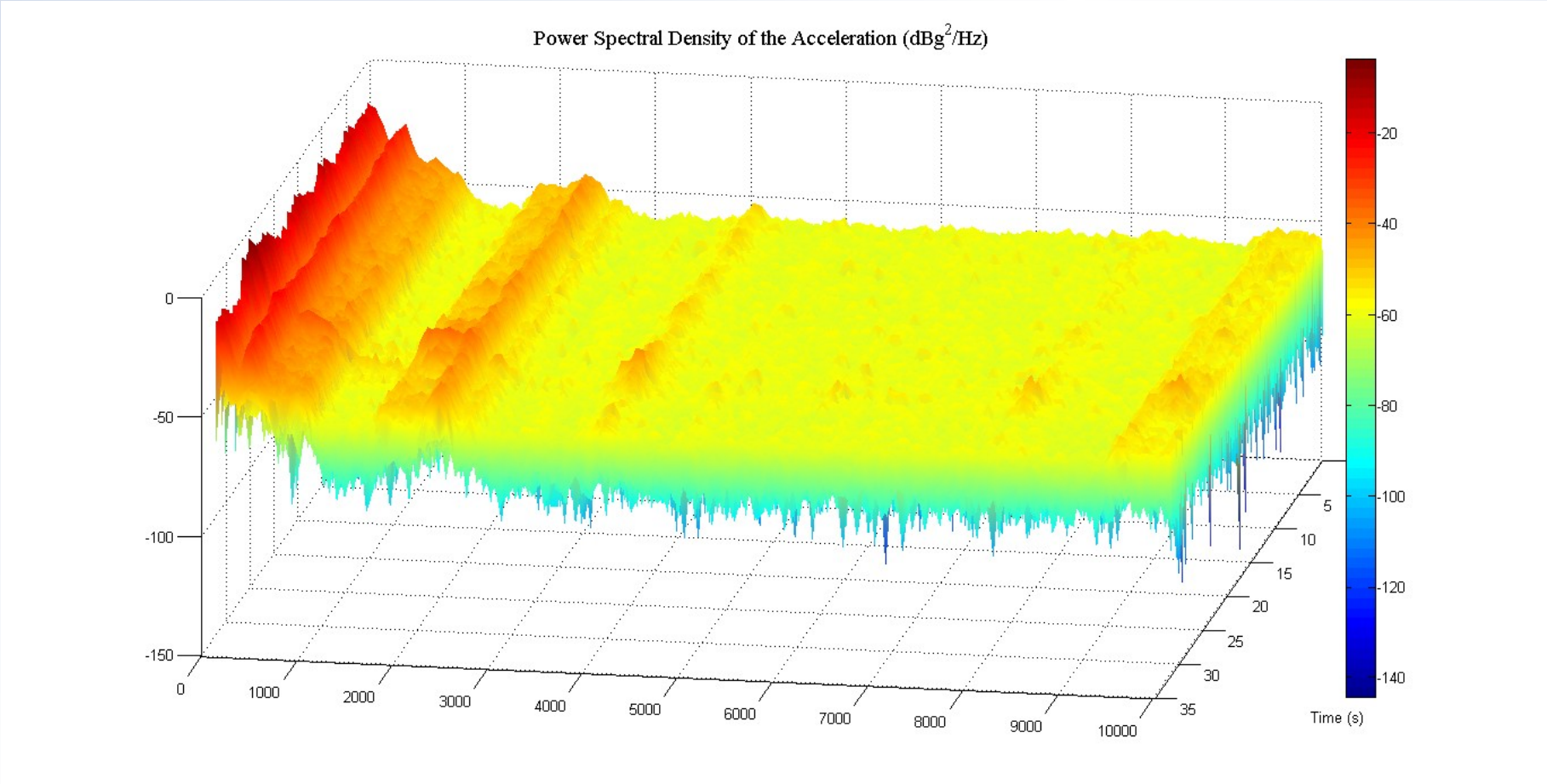






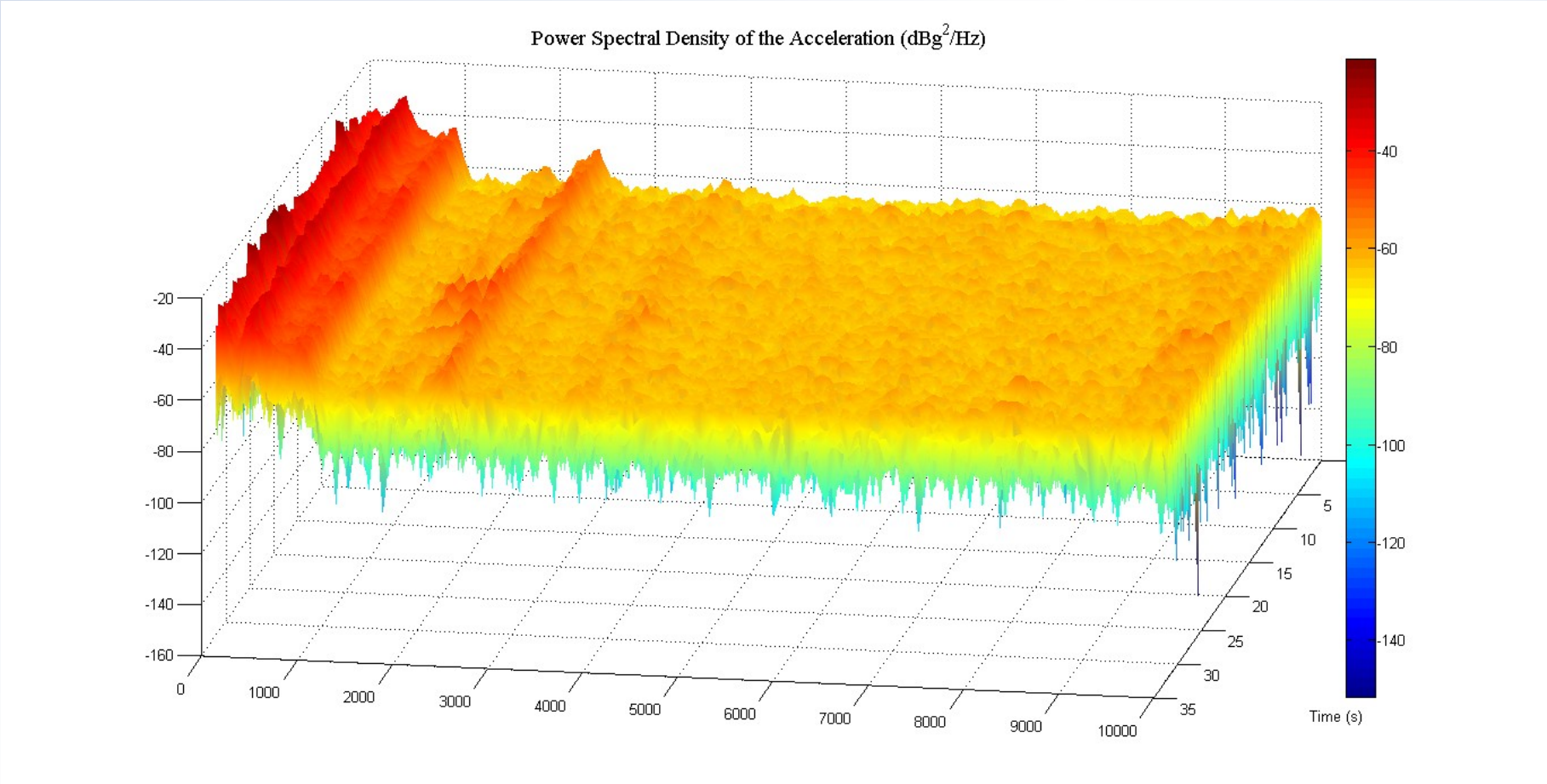
Vibration database – signals for the tests

PSD OF THE VIBRATION TIME SERIES OF A BICYCLE



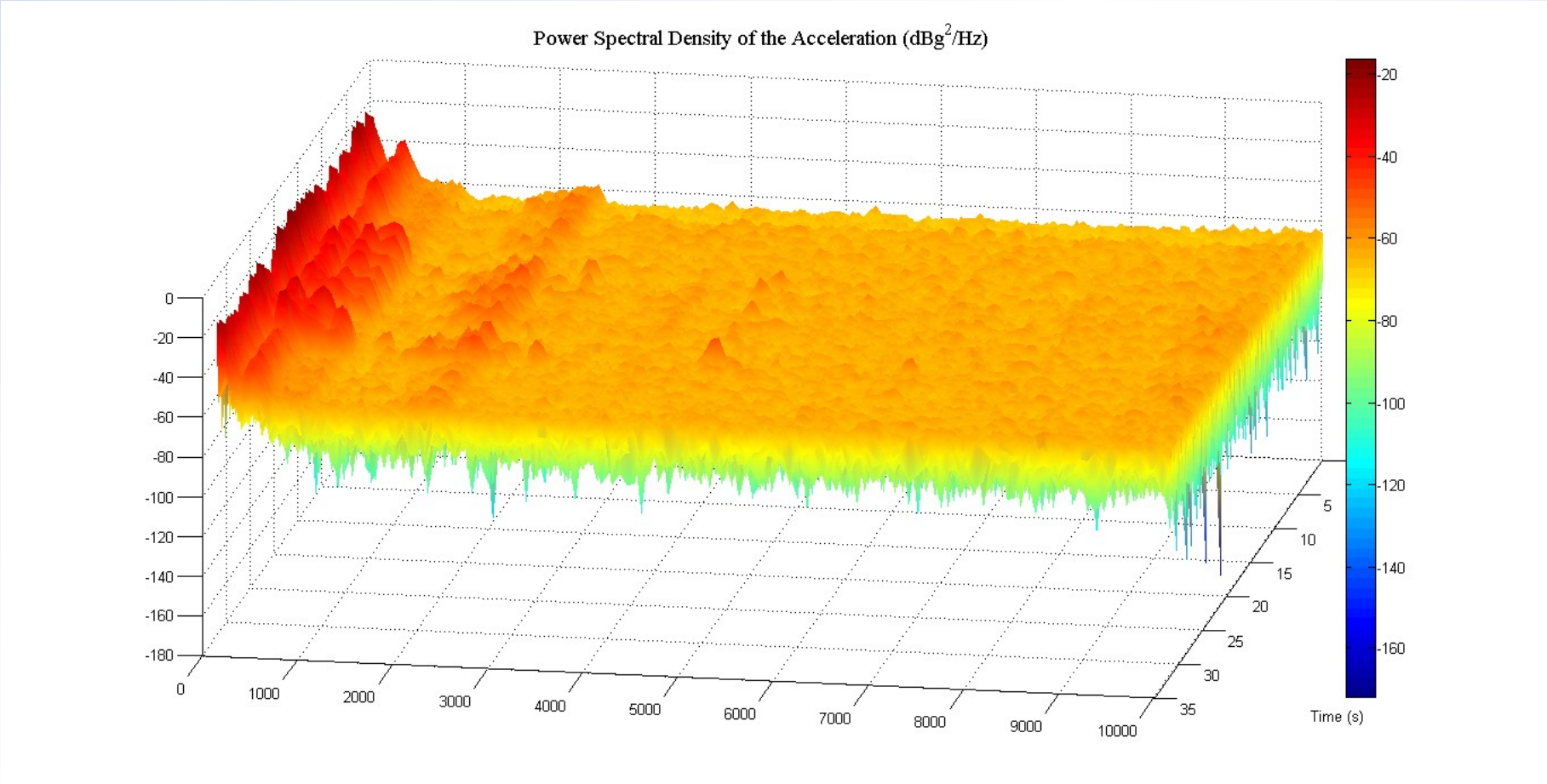
Vibration database – signals for the tests

PSD OF THE VIBRATION TIME SERIES OF A CAR ON HIGHWAY



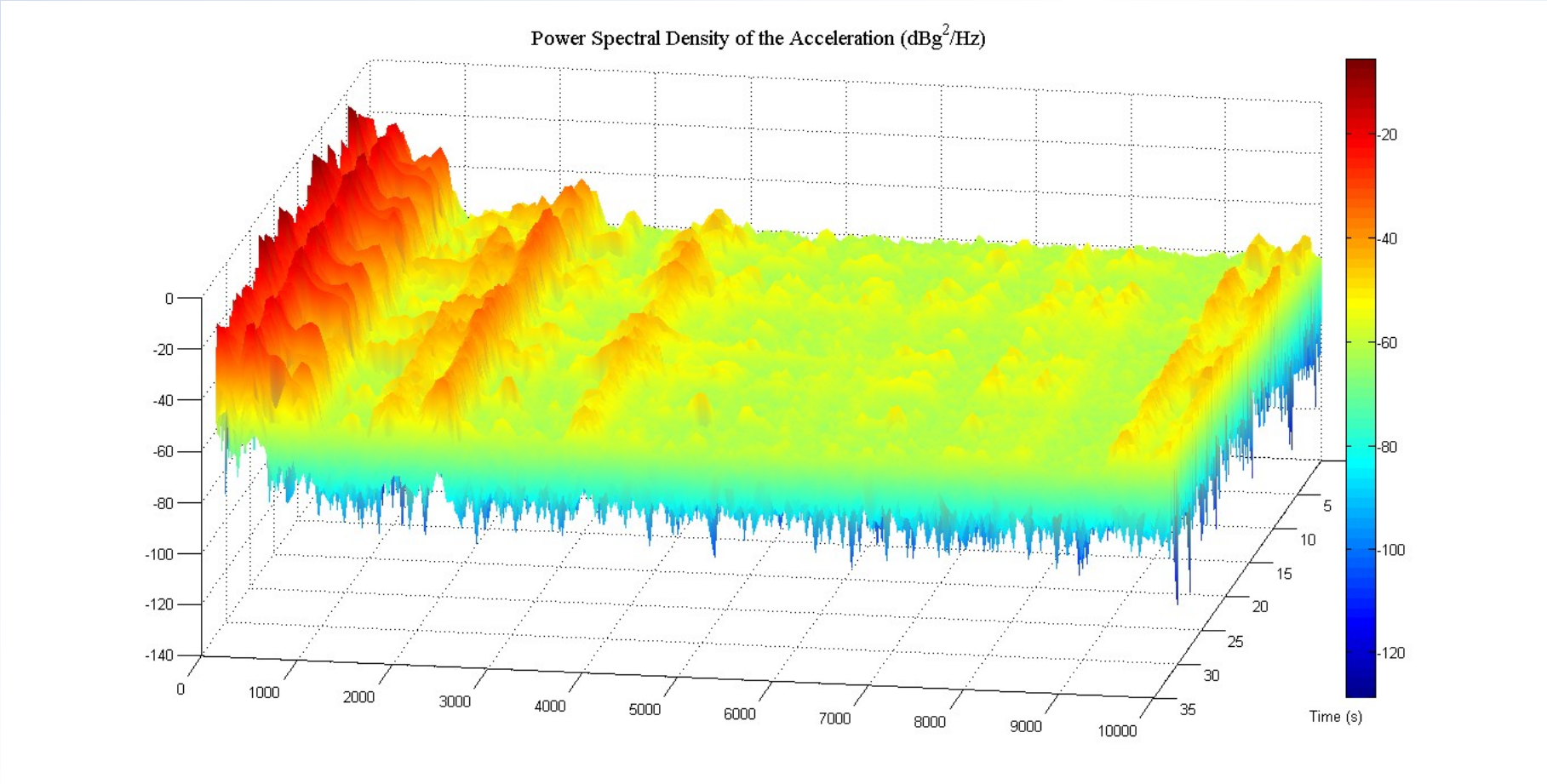
Vibration database – signals for the tests

PSD OF THE VIBRATION TIME SERIES OF A CAR ON URBAN ROAD

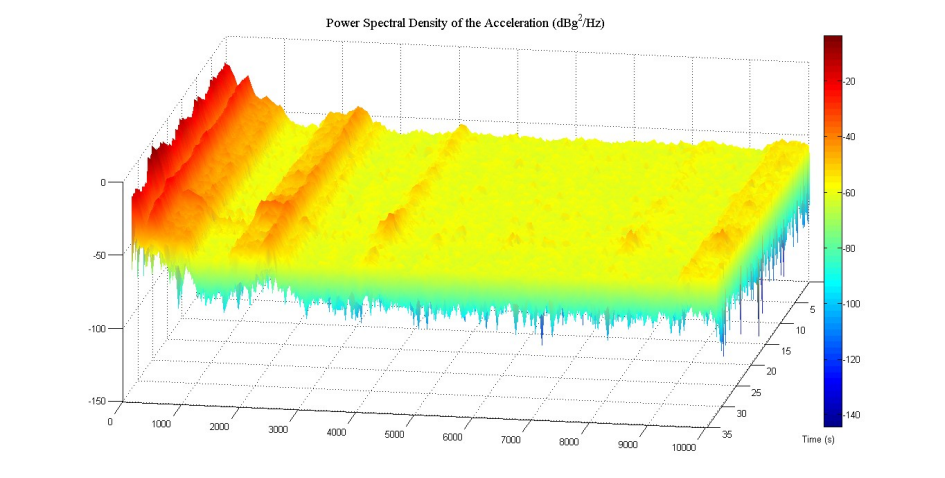


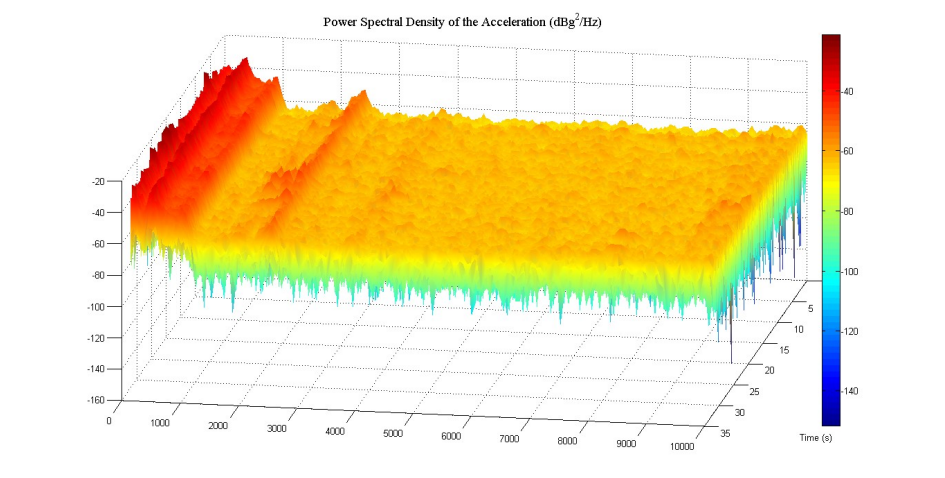
Vibration database – signals for the tests

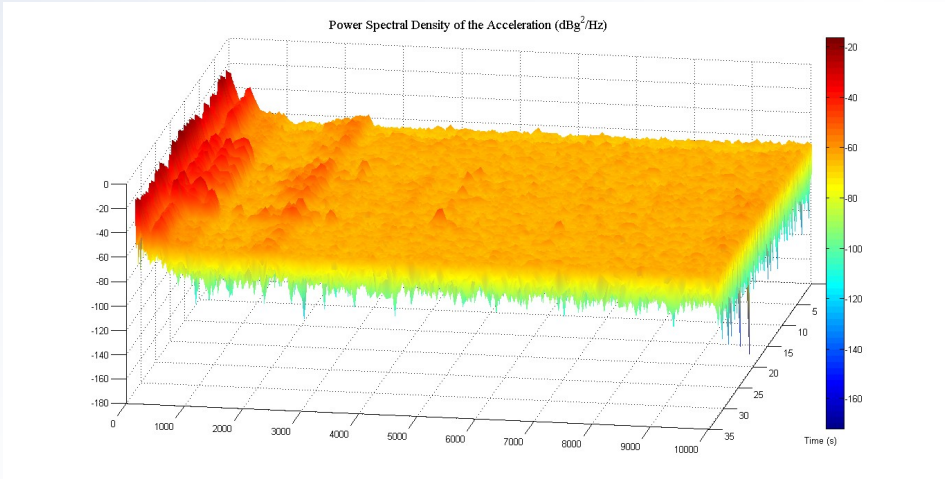
PSD OF THE VIBRATION TIME SERIES OF A WHEEL AXLE

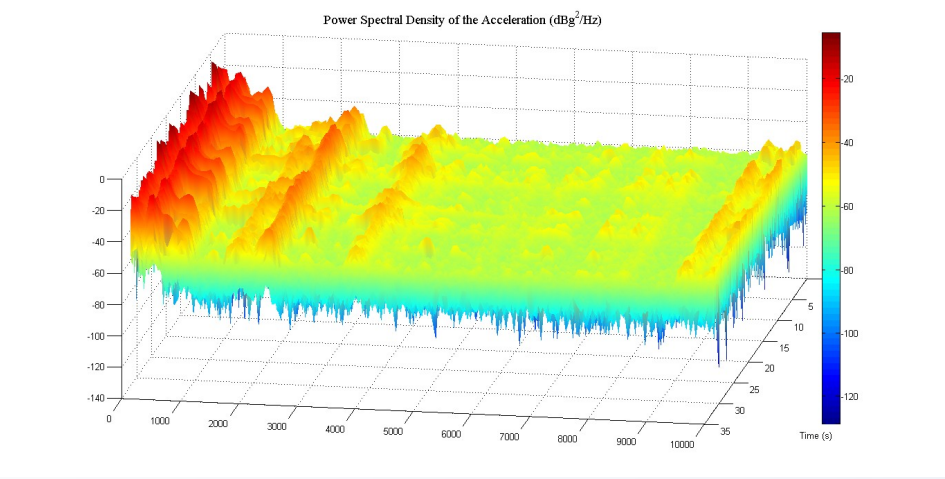


Vibration database – signals for the tests





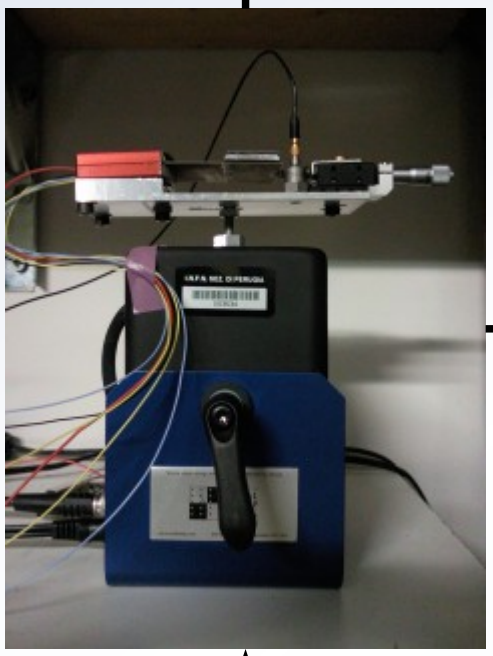




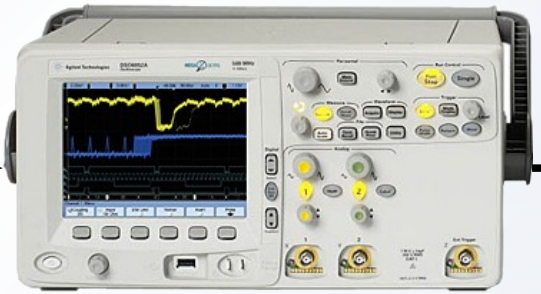
Test setup

http://realvibrations.nipslab.org

Accelerometer



Ch.2



Agilent
MSO6032A

PZT

Cantilever

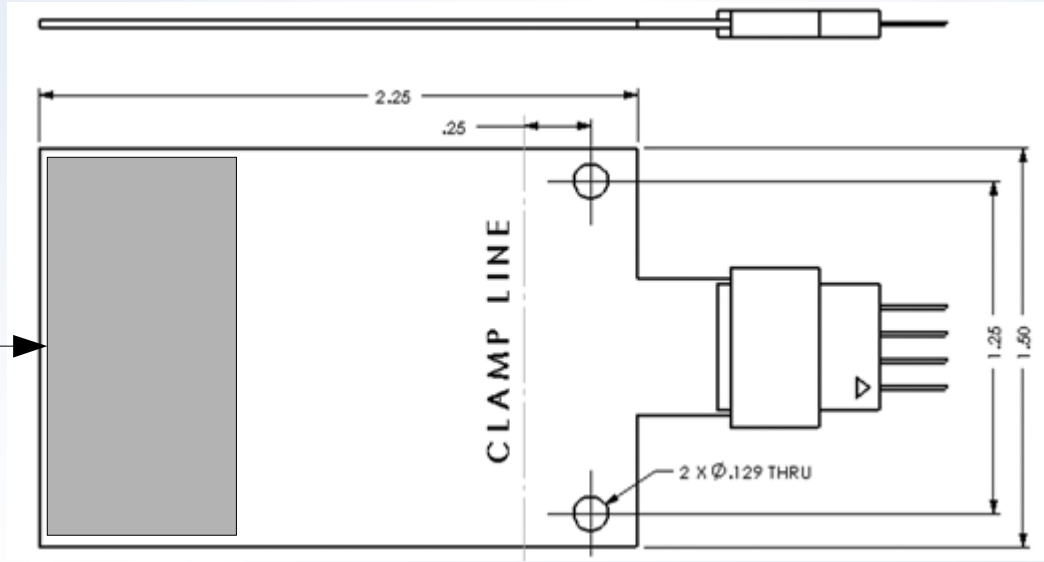
Ch.1

Agilent 33210A

Preliminary tests of the piezoelectric harvester

50 GR TIP MASS

RESONANT FREQUENCY DOWN TO 37,5 HZ

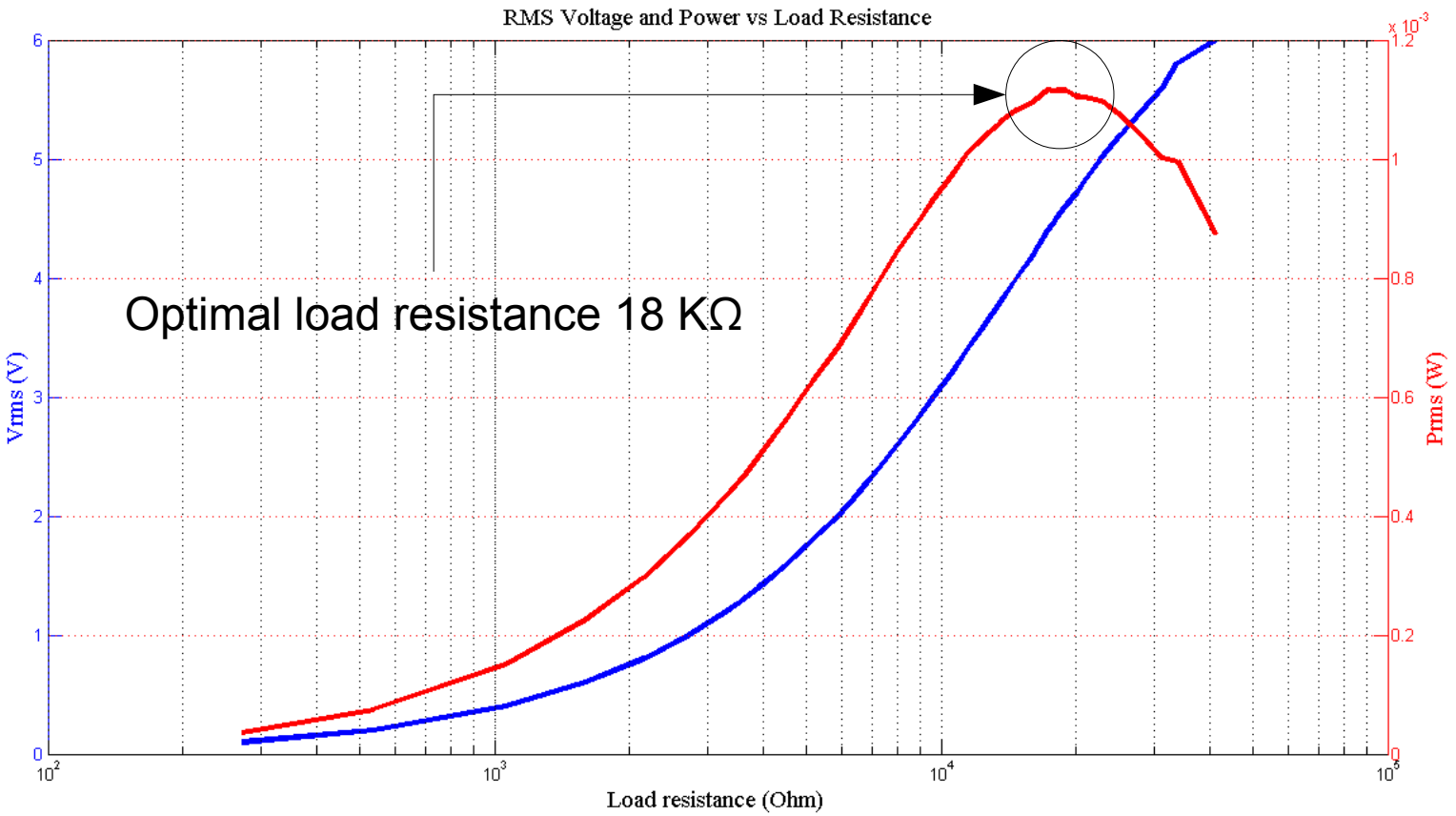


Midé V20w

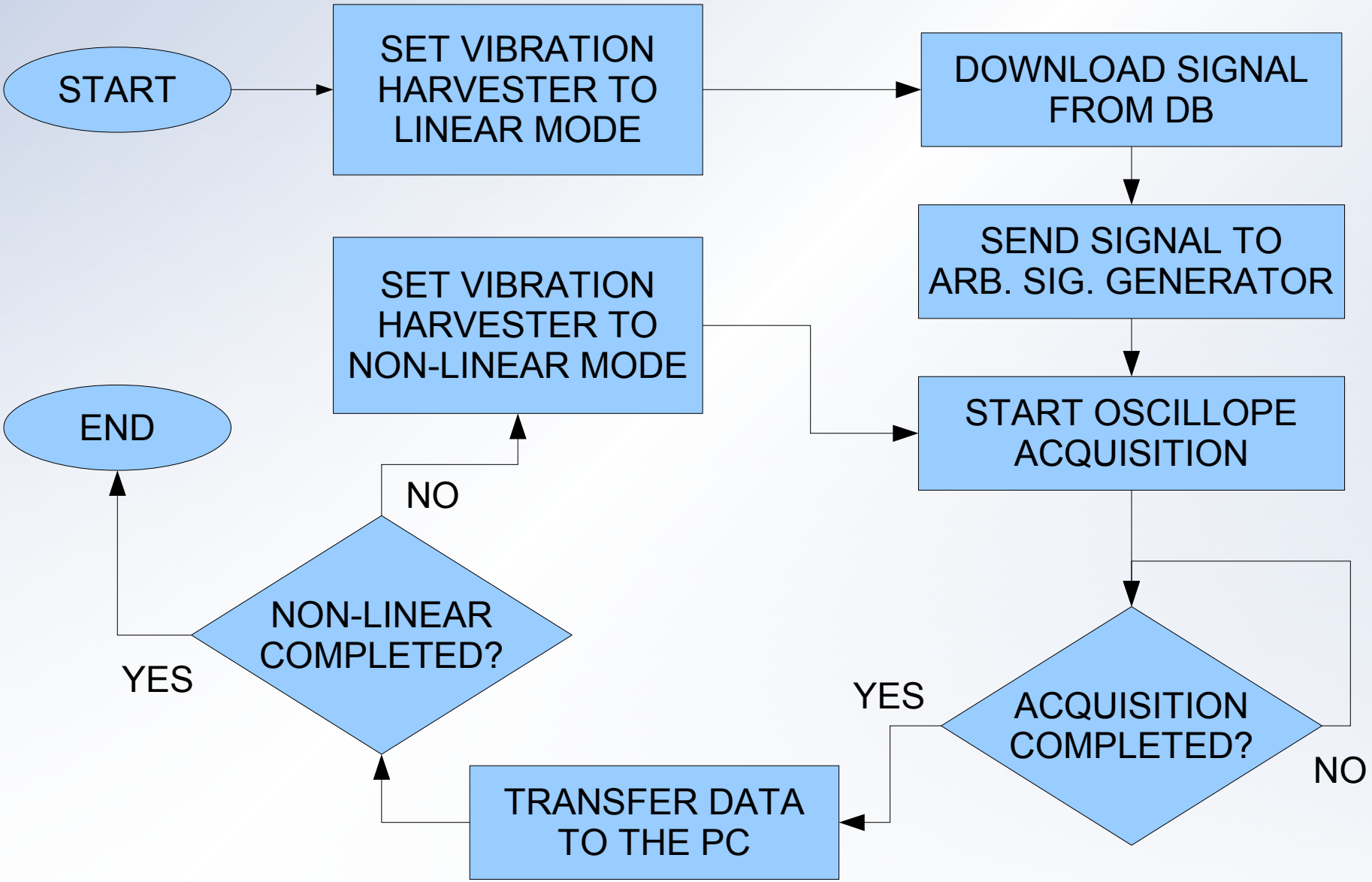
Frequency Range (Hz):	75-175	Not suitable for our application!
Harvesting Bandwidth (Hz):	3	
Device size (in):	2.00 x 1.00 x 0.03	
Device weight (oz):	0.28	
Active elements:	1 stack of 2 piezos	
Piezo wafer size (in):	1.81 x 1.31 x 0.010	
Device capacitance (μF):	0.2	

Preliminary tests of the piezoelectric harvester

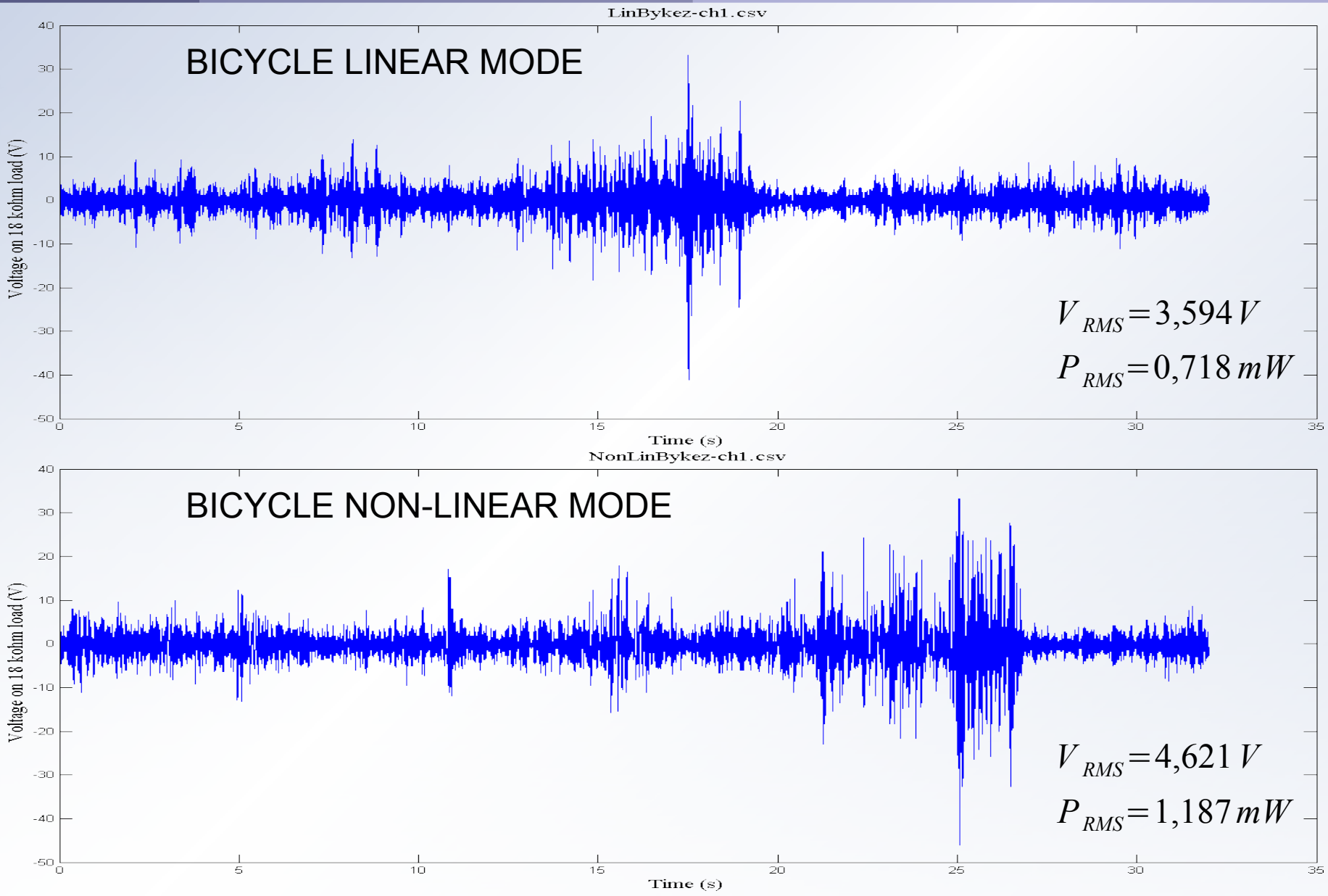
POWER vs LOAD RESISTANCE AT THE RESONANT FREQUENCY OF 37,5 Hz



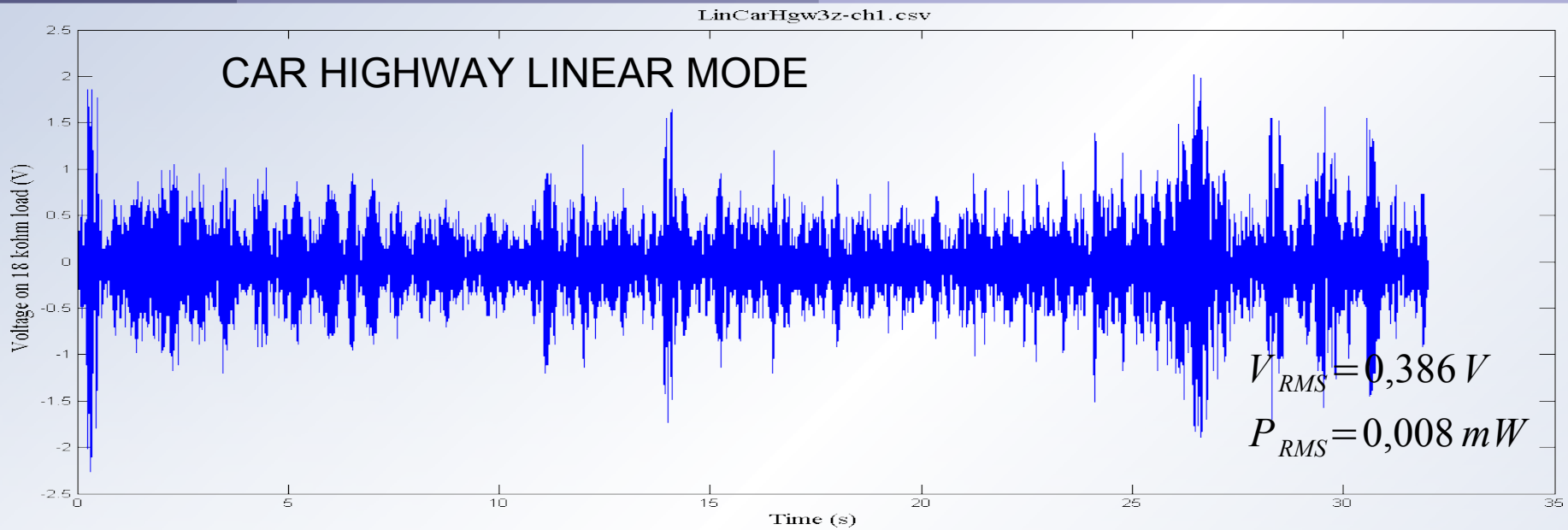
Test procedure

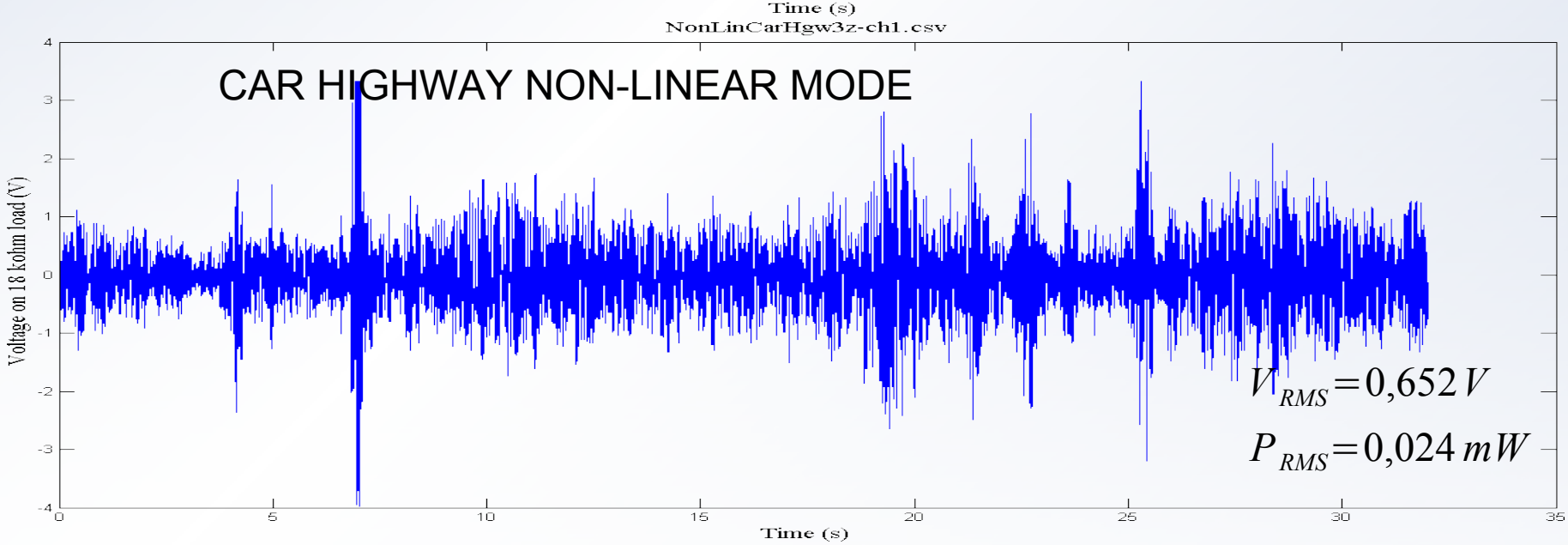


Linear mode vs non-linear mode tests (1/5)

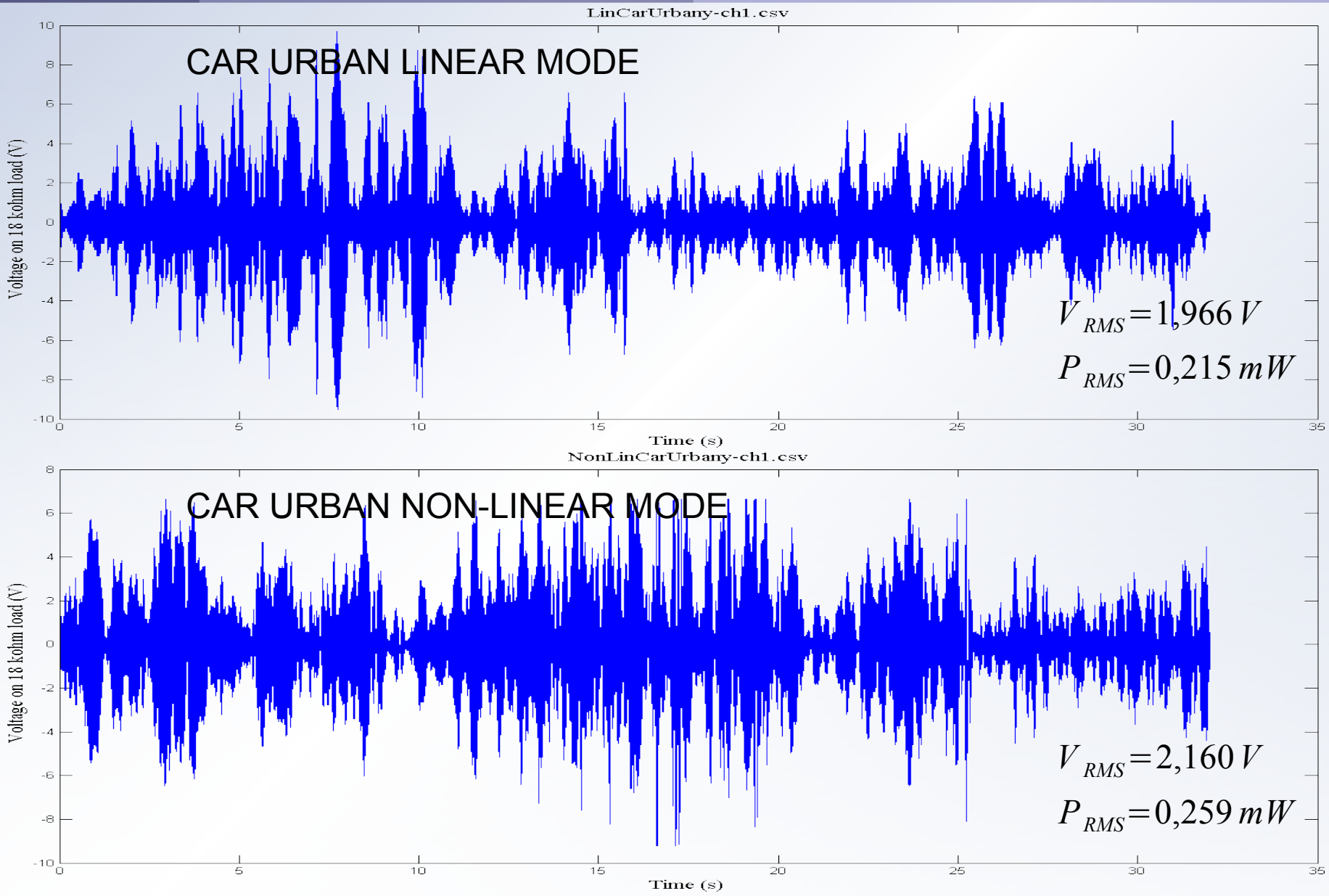


Linear mode vs non-linear mode tests (2/5)

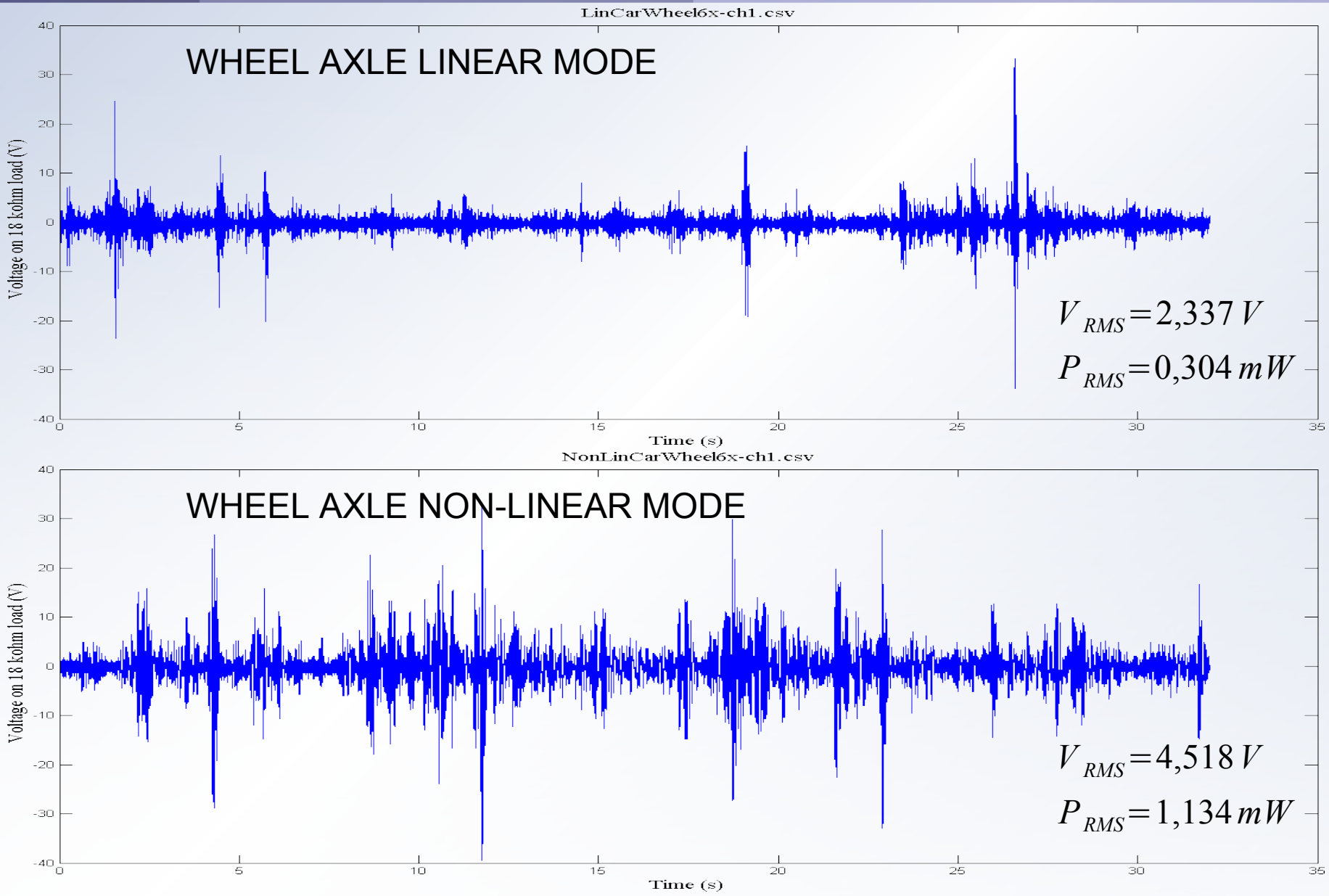




Linear mode vs non-linear mode tests (3/5)



Linear mode vs non-linear mode tests (4/5)



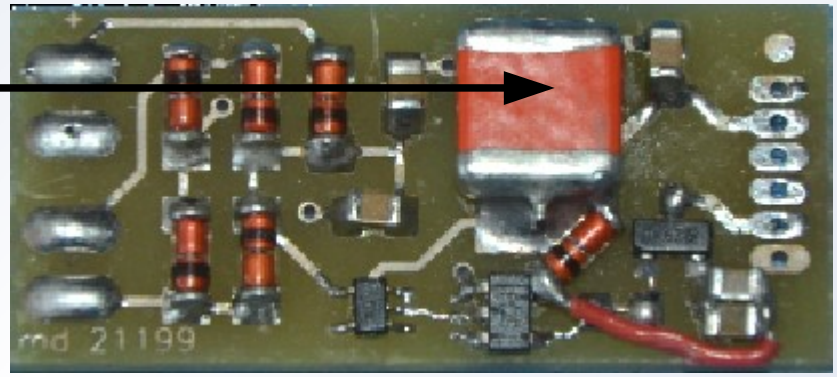
Linear mode vs non-linear mode tests (5/5)

VIBRATION	ACCEL. g_{RMS}	RMS VOLTAGE LINEAR MODE	RMS VOLTAGE NON-LINEAR MODE	RMS POWER LINEAR MODE	RMS POWER NON-LINEAR MODE
BICYCLE	**0.848**	**3.594 V**	**4,621 V**	**0,718 mW**	**1,187 mW**
CAR ON HIGHWAY	0,180	0.386 V	0.652 V	0,008 mW	0,024 mW
CAR ON URBAN ROAD	0,307	1.966 V	2.160 V	0,215 mW	0,259 mW
WHEEL AXLE	**0,844**	**2,337 V**	**4,518 V**	**0,304 mW**	**1,134 mW**

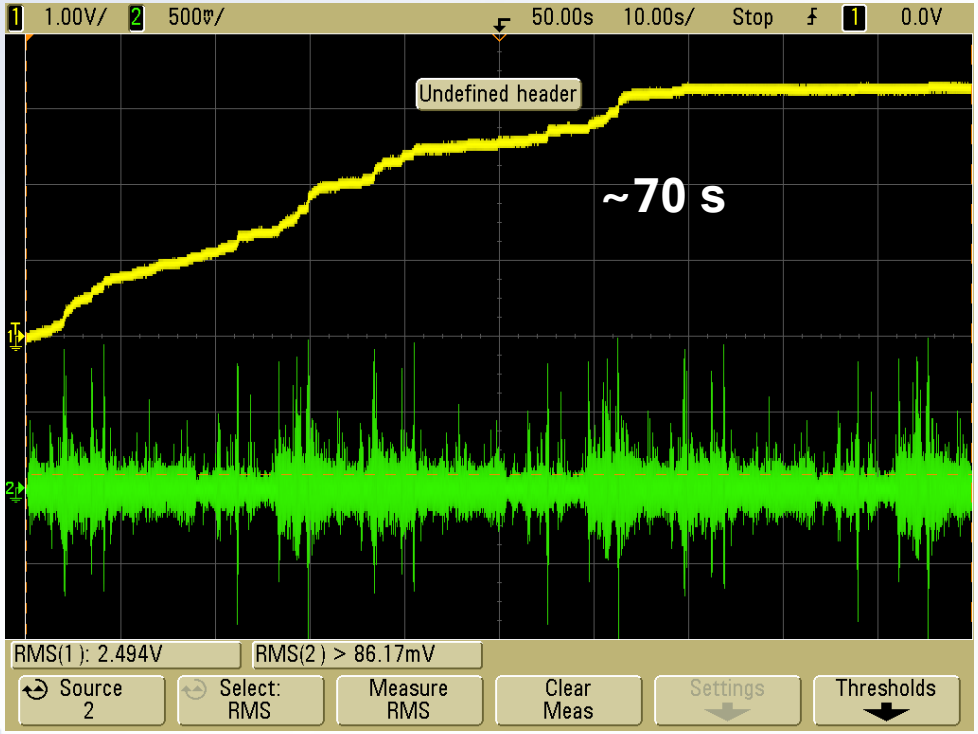
A practical example

CHARGING A 1000 µF TANTALUM CAPACITOR UP TO 3,3 V

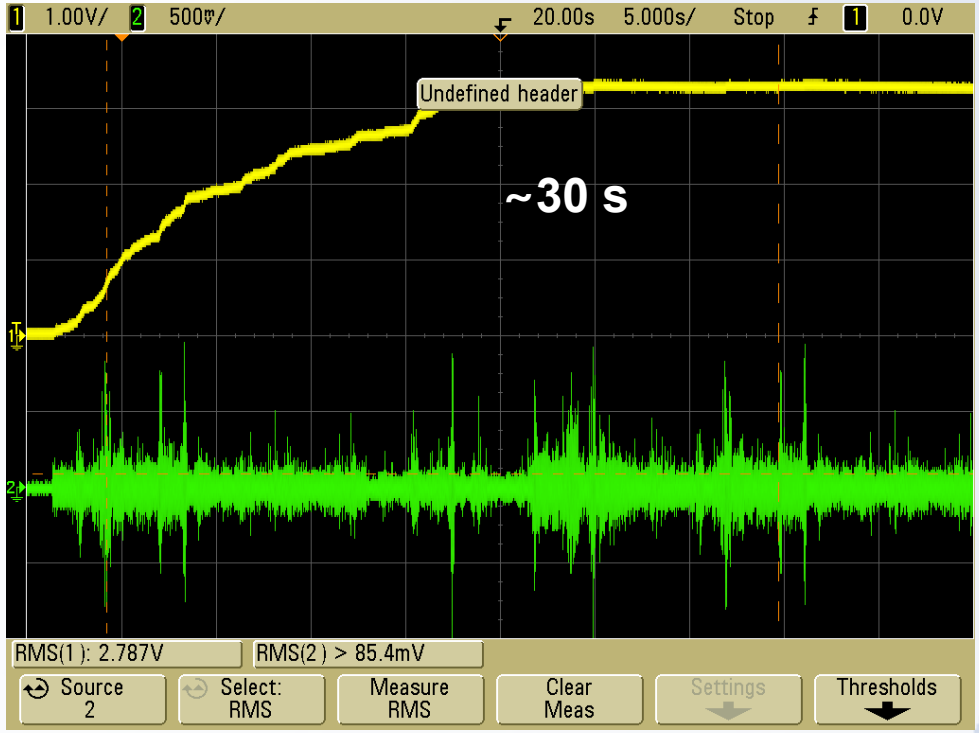
$$Q = \frac{1}{2} C V^2$$



LINEAR MODE



NON-LINEAR MODE



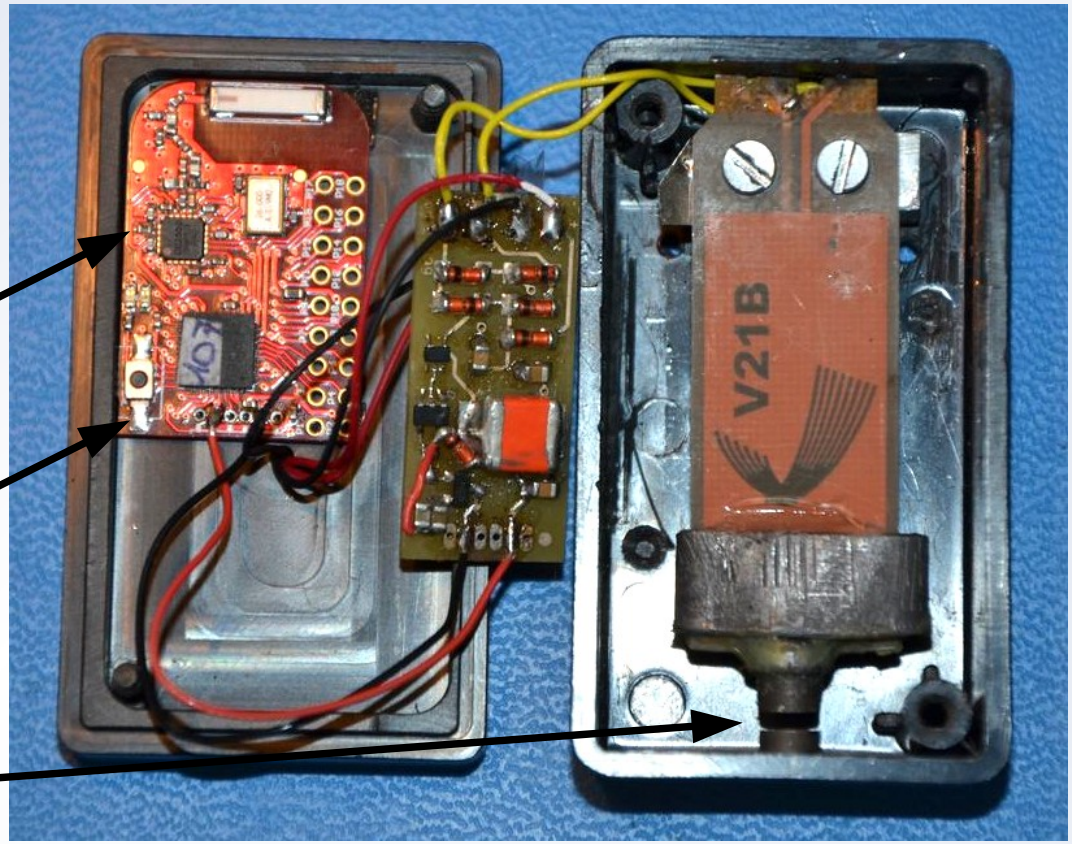
A real application

SMALL VIBRATION POWERED WIRELESS TEMPERATURE SENSOR OPERATING ON 2,4 GHz ISM BAND

2,4 GHz TRANSCEIVER

16 bit MSP430 µCONTROLLER

MAGNETS



- Small enclosure: 60 x 35 x 25 mm
- 1 piezoelectric non-linear vibrations harvester
- 1 LDO voltage regulator: Vout = 3,3 Vdc, Iq = 3,2 µA
- 1 high capacitance tantalum capacitor: 1000 µF 6,3 V
- 1 NanoPower Supervisory Circuits

WISEPOWER

http://www.wisepower.it

Conclusions

- A method to simulate a pseudo-real working conditions has been proposed.
- An estimation of the power that can be converted has been proposed in some typical cases.
- The superiority of the non-linear vibration energy harvester with respect the linear one has been demonstrated and it is always evident.
- **The energy converted by the non-linear energy harvester is almost constant in case of vibrations with different PSD but almost the same RMS value of the accelerations.**

THANK YOU