Experimental evidences of high frequency and short wavelength VIV on long stay cables

LIÈGE université
Structural and Stochastic Dynamics

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Seminar on: Modelling Vortex Resonance
Ruhr-Universiteit Bochum
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Context

$$f_s = \frac{USt}{D}$$

$$S_L(f,z) \sim \exp\left[-\frac{1}{B^2(z)}\left(1-\frac{f}{f_s(z)}\right)^2\right]$$

relative bandwidth — Shedding frequency

$g(s)$ in eqn. (28) was generated as a narrow-band Gaussian random variable with zero mean, unit variance and a relative bandwidth of 0.1; the centre wavenumber was set equal to S/D. The relative bandwidth of 0.1 is representative of smooth flow.

(This number has been adjusted for chimneys.)

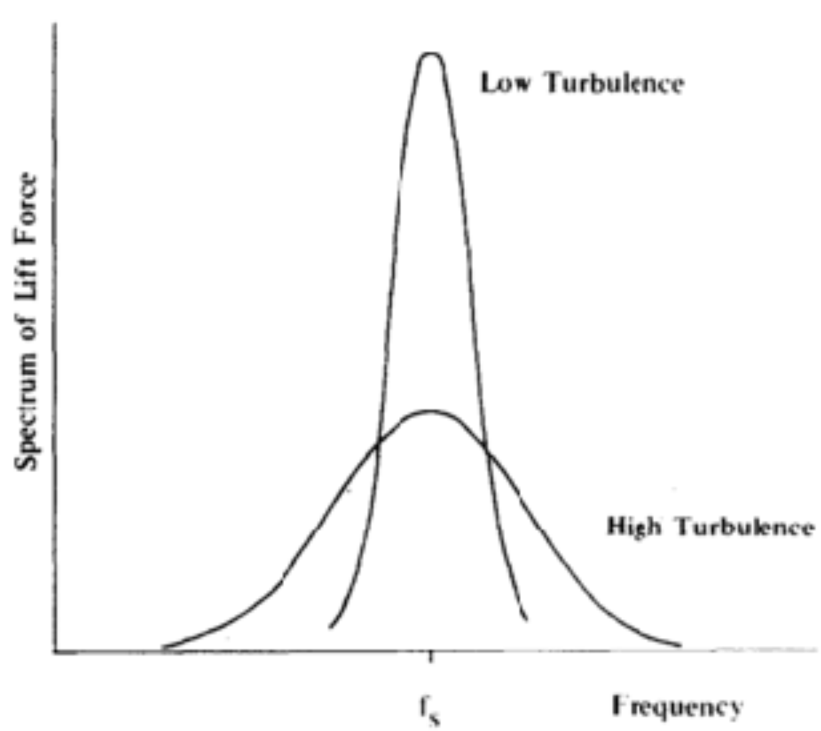

Fig. 1. Form of spectrum of lift force due to vortex shedding.

Model by Vickery and Clark, ASCE, 1972

Context


Former NATO antenna
254-m high
3m x 3m Truss tower & 20 pairs of stay cables

Context


Vibration Monitoring of the Pylon in Houtem
(June 2015) - Height 254 m.

Description of the pylon

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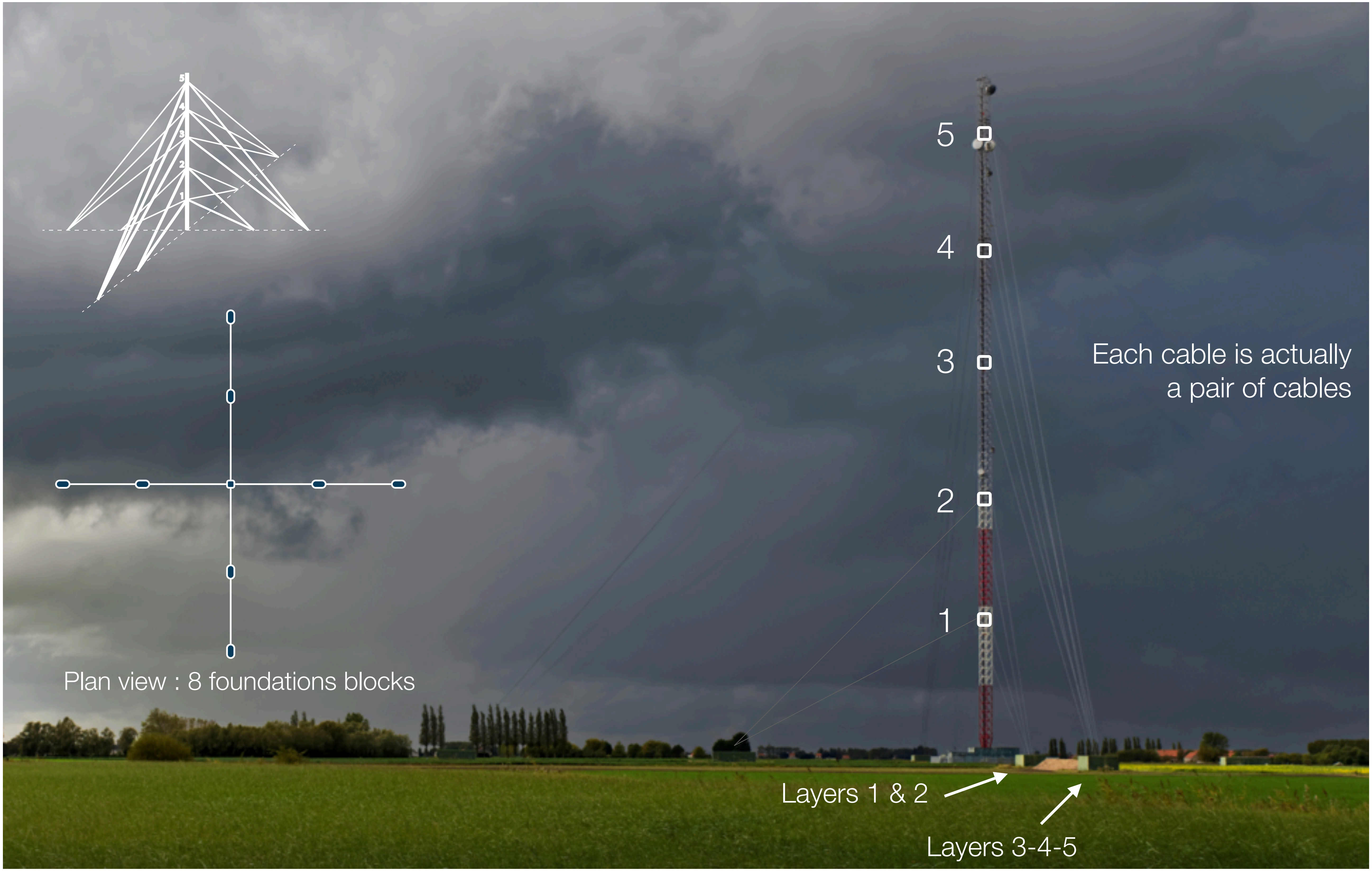
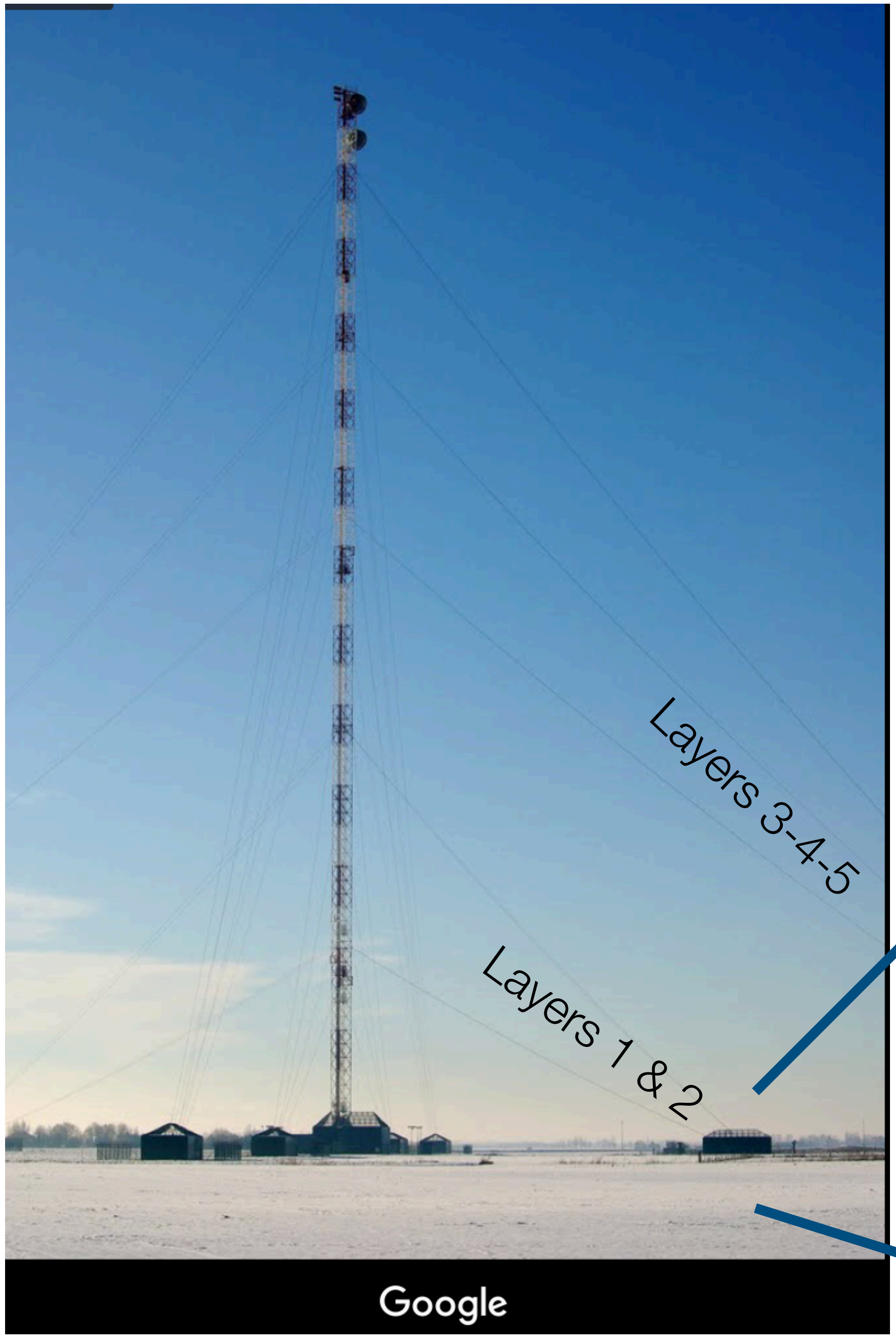
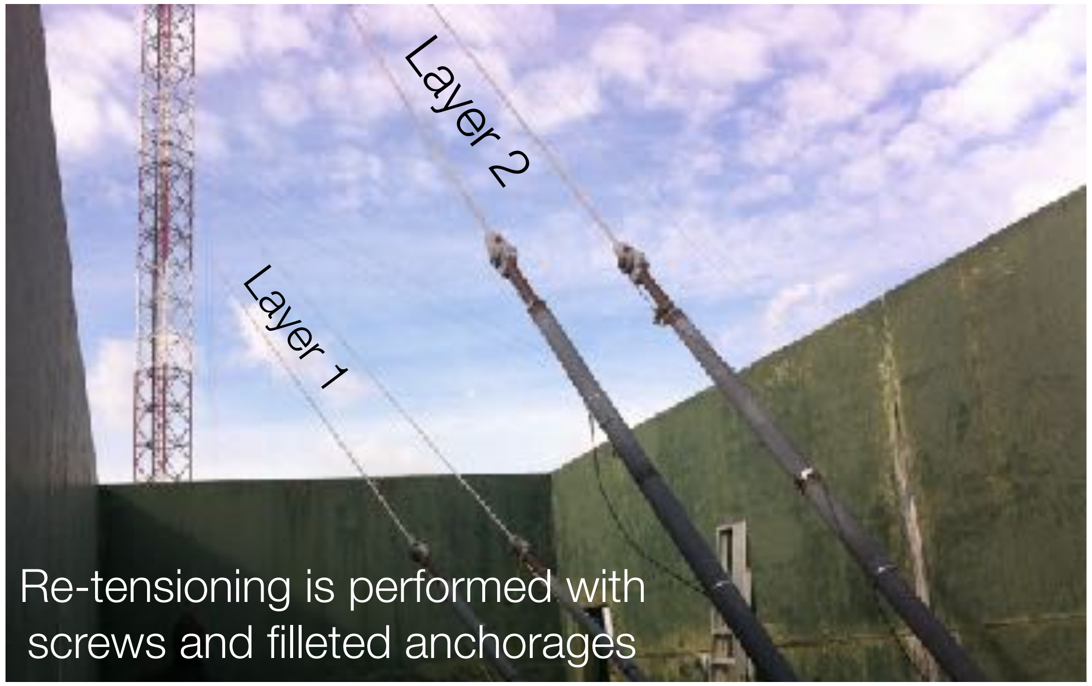


Description of the pylon





Description of the pylon

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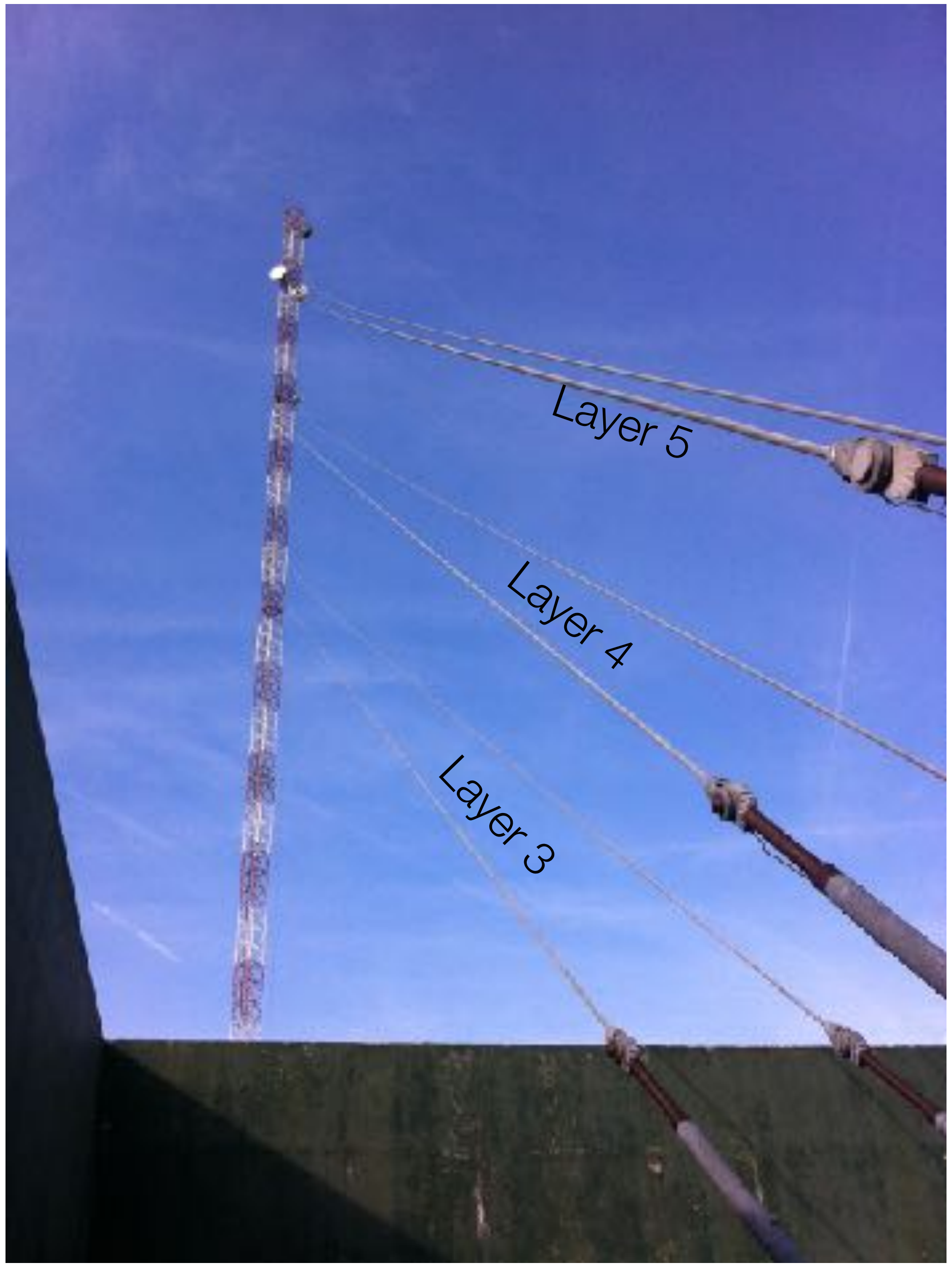

Some numbers

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- Longest cable, almost 300 meters long
- Diameters from 24 mm to 42 mm
- Sub-crossover regime (low Irvine parameter, from 0.45 to 9)
- Low fundamental natural frequency (0.28 Hz to 0.88 Hz)

	Cable 1	Cable 2	Cable 3	Cable 4	Cable 5
Nominal pretension [kN]	111.2	163.6	150	192	237
Top anchorage height [m]	47	95	143	185	227
Anchorage foot offset [m]	102.1	102.1	182.9	182.9	182.9
Cable length [m]	112.4	139.5	232.2	260.1	291.5
Cable angle [°]	24.7	42.9	38.0	45.3	51.1
Cable diameter [mm]	24	28	26	30	42
Cable Young modulus [MPa]	175000	175000	175000	175000	175000
Lineic mass [kg/m]	2.84	3.87	3.33	4.43	8.70
Sag-to-span ratio [-]	0.35%	0.40%	0.63%	0.74%	1.31%
Irvine parameter λ^2 [-]	0.45	0.55	1.27	1.79	9.01
Nominal fundamental frequency [Hz]	0.88	0.74	0.46	0.40	0.28

The Problem

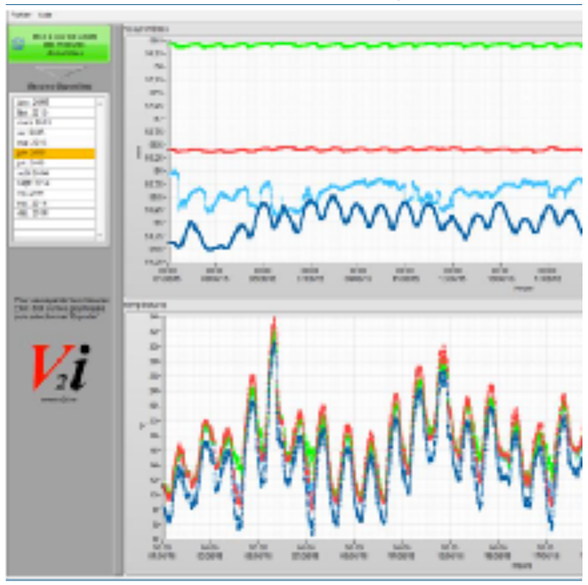
Investigation tracks

- Near the see, Cat-0 terrain, very low turbulence intensity
- Several cables, with different skew angles, show simultaneous vibrations —> not dry galloping
- Vibrations happen in various weather conditions —> not rain-wind vibration
- Vibrations occur at low to medium wind velocity, seem to disappear for higher velocities
  - More turbulence at high velocity
  - More aerodynamic damping at high velocity

Vortex-Induced Vibrations

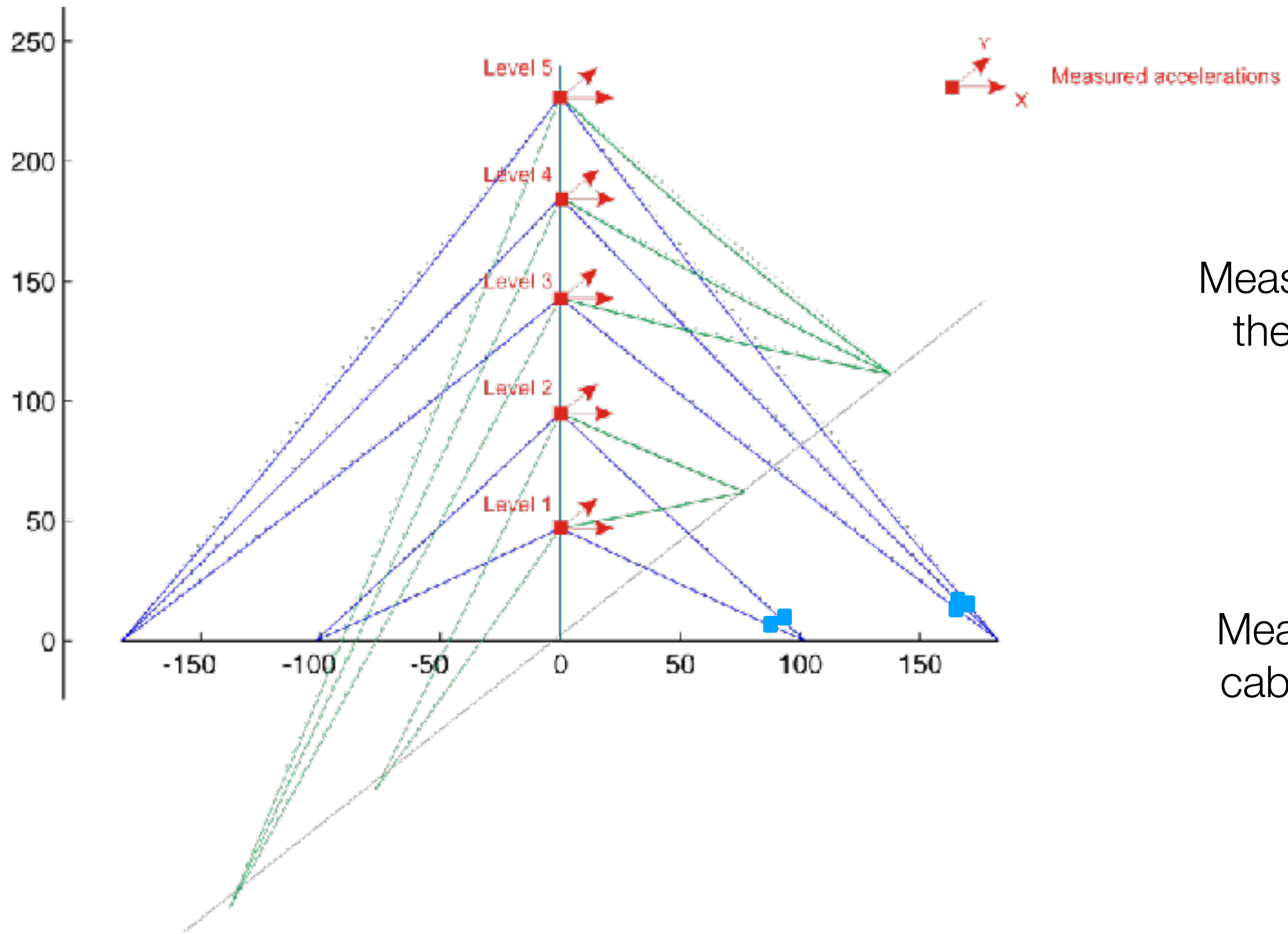
Evaluation campaign

Monitoring



Mitigation

Evaluation campaign



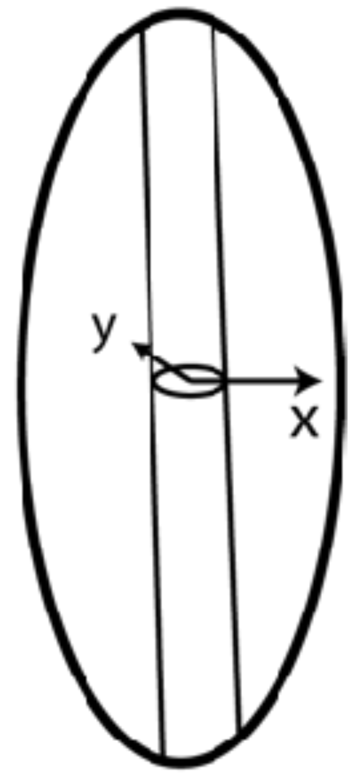
Phase I

Measure acceleration on the cables and pylon

Phase II

Measure accelerations cables only (long-term monitoring)

Position of the sensors on the cable



Measured acceleration on the cable

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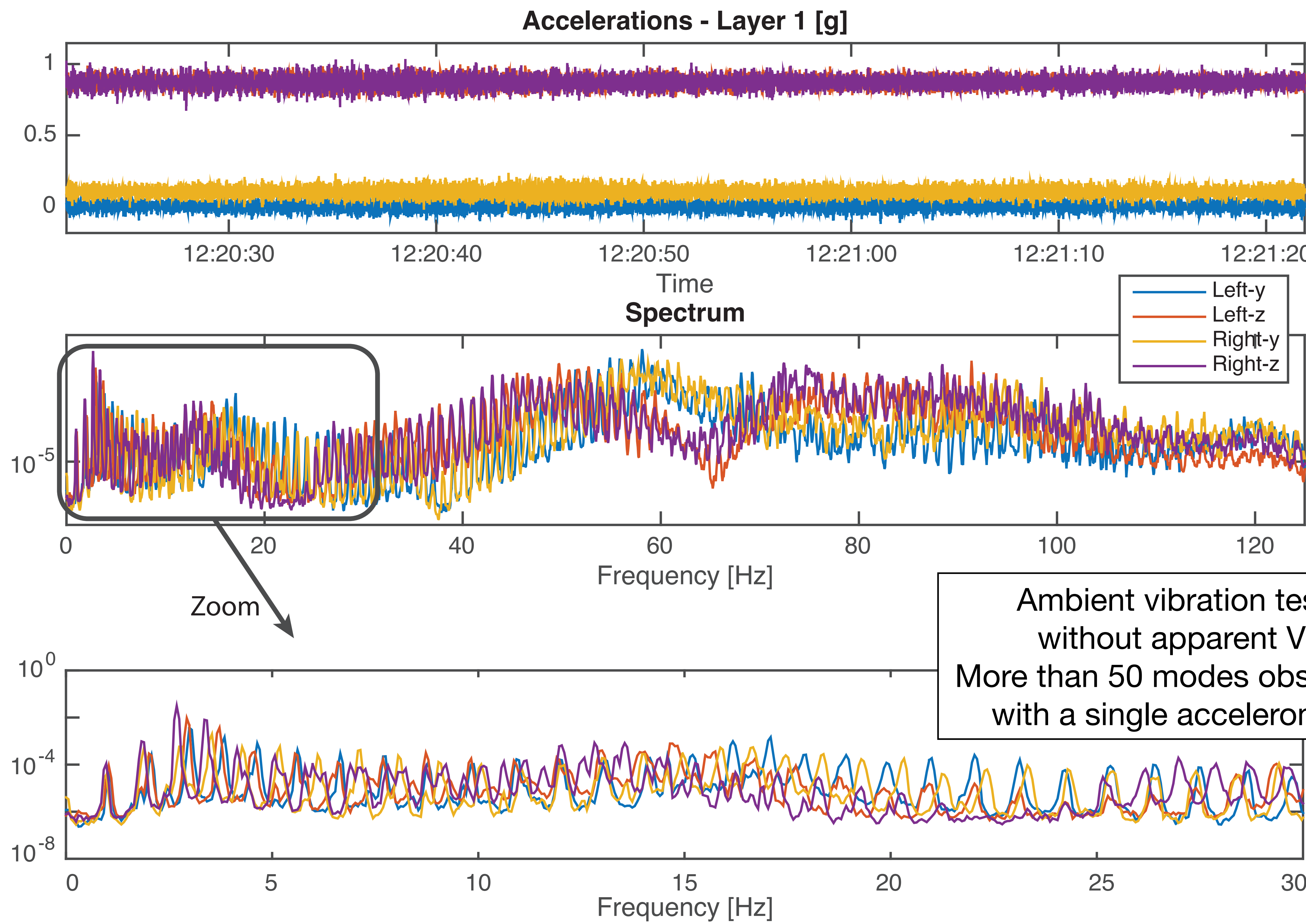
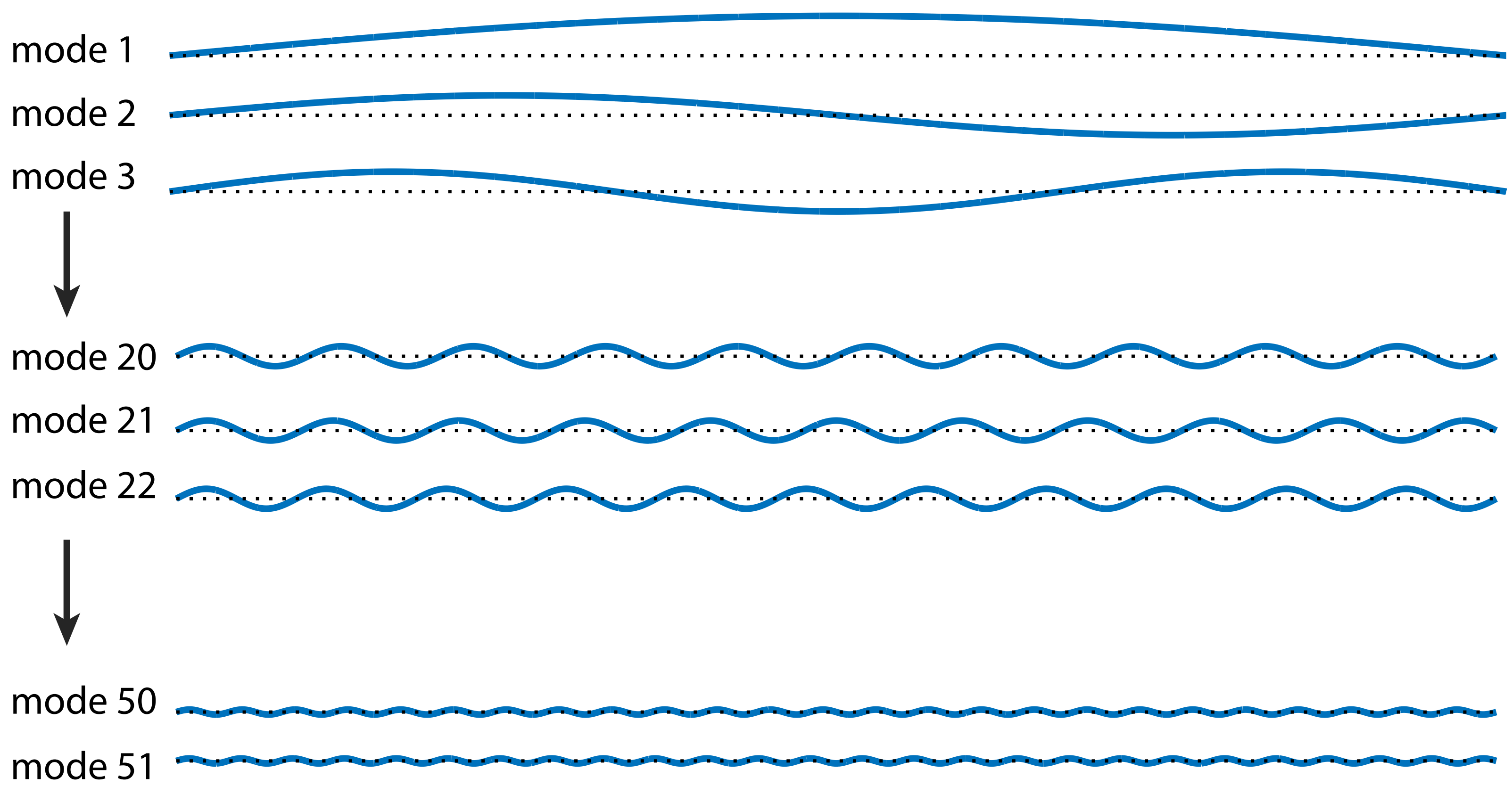
Without VIV

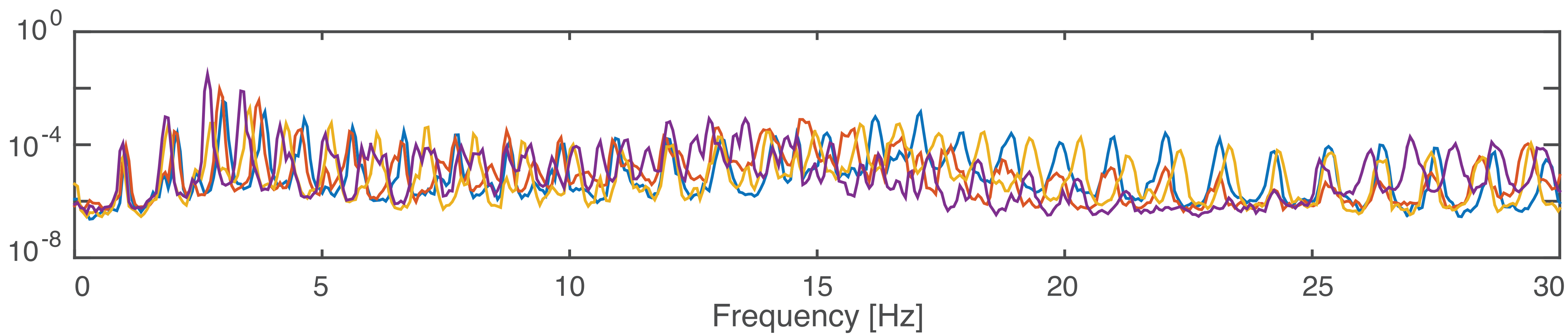


Ambient vibration tests,
without apparent VIV
More than 50 modes observable
with a single accelerometer

Measured acceleration on the cable

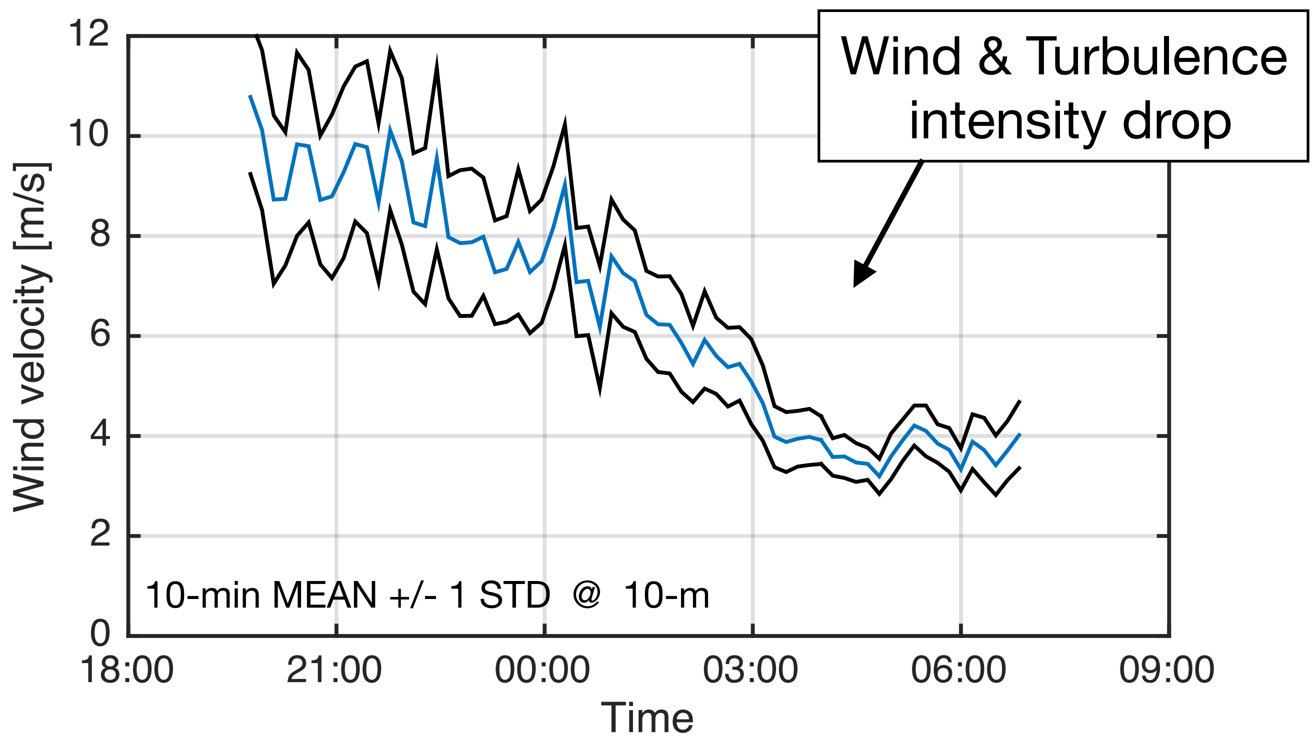
Without VIV

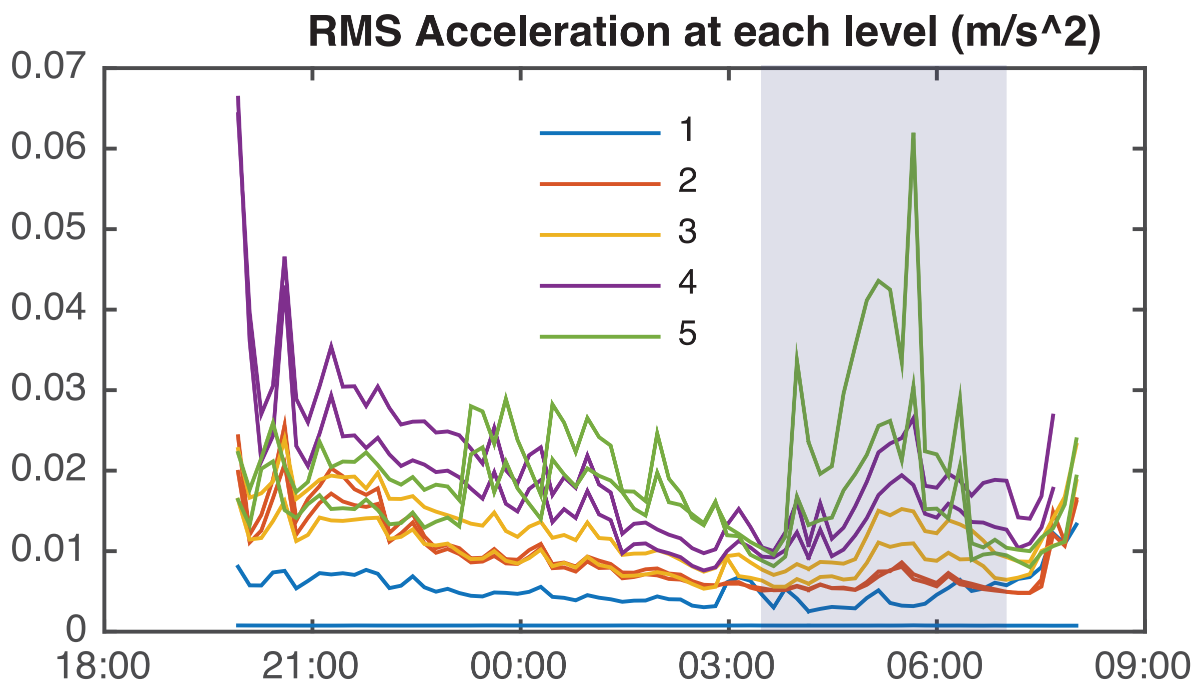


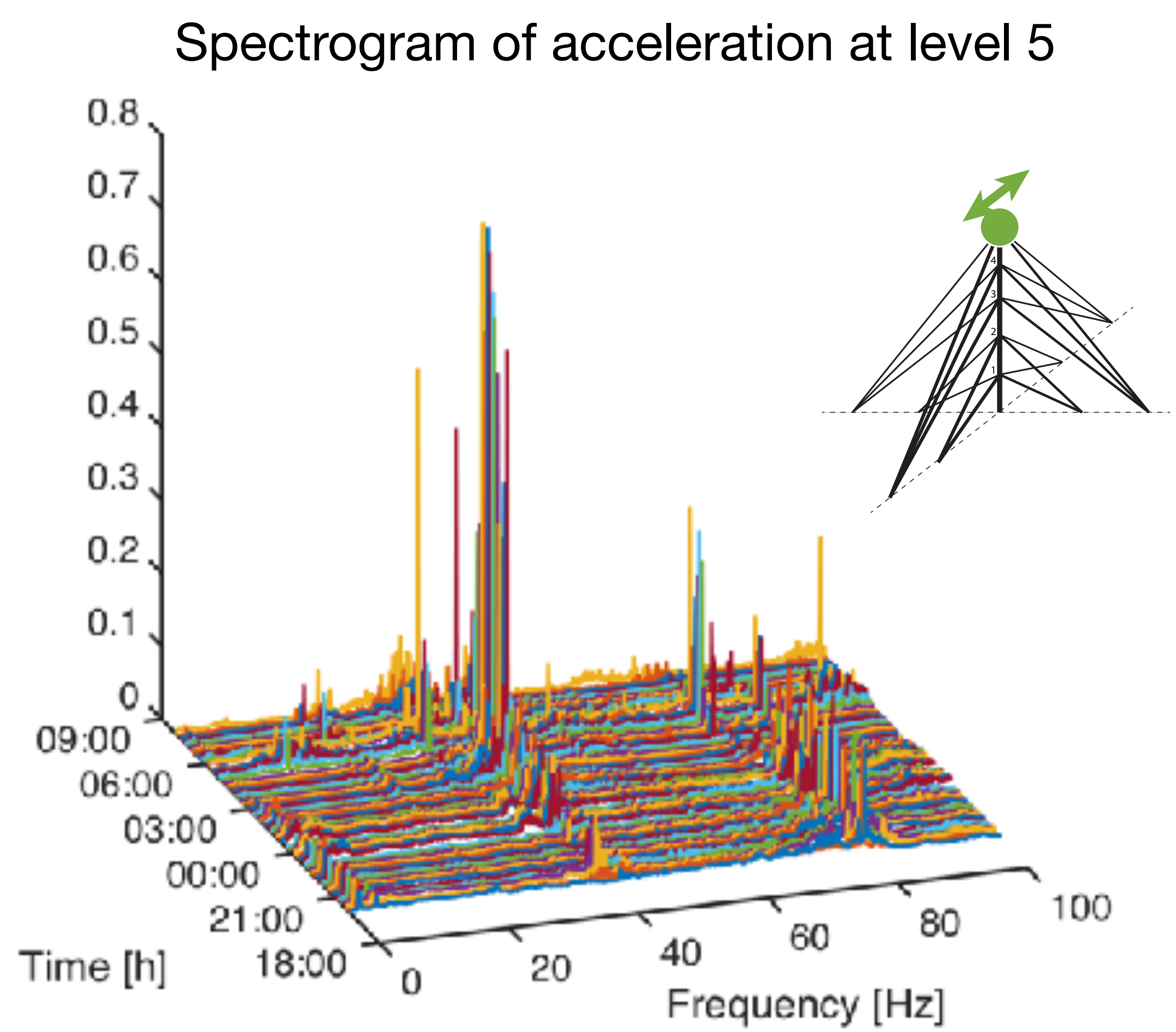


Measured acceleration on the cable

Example of an overnight measurement

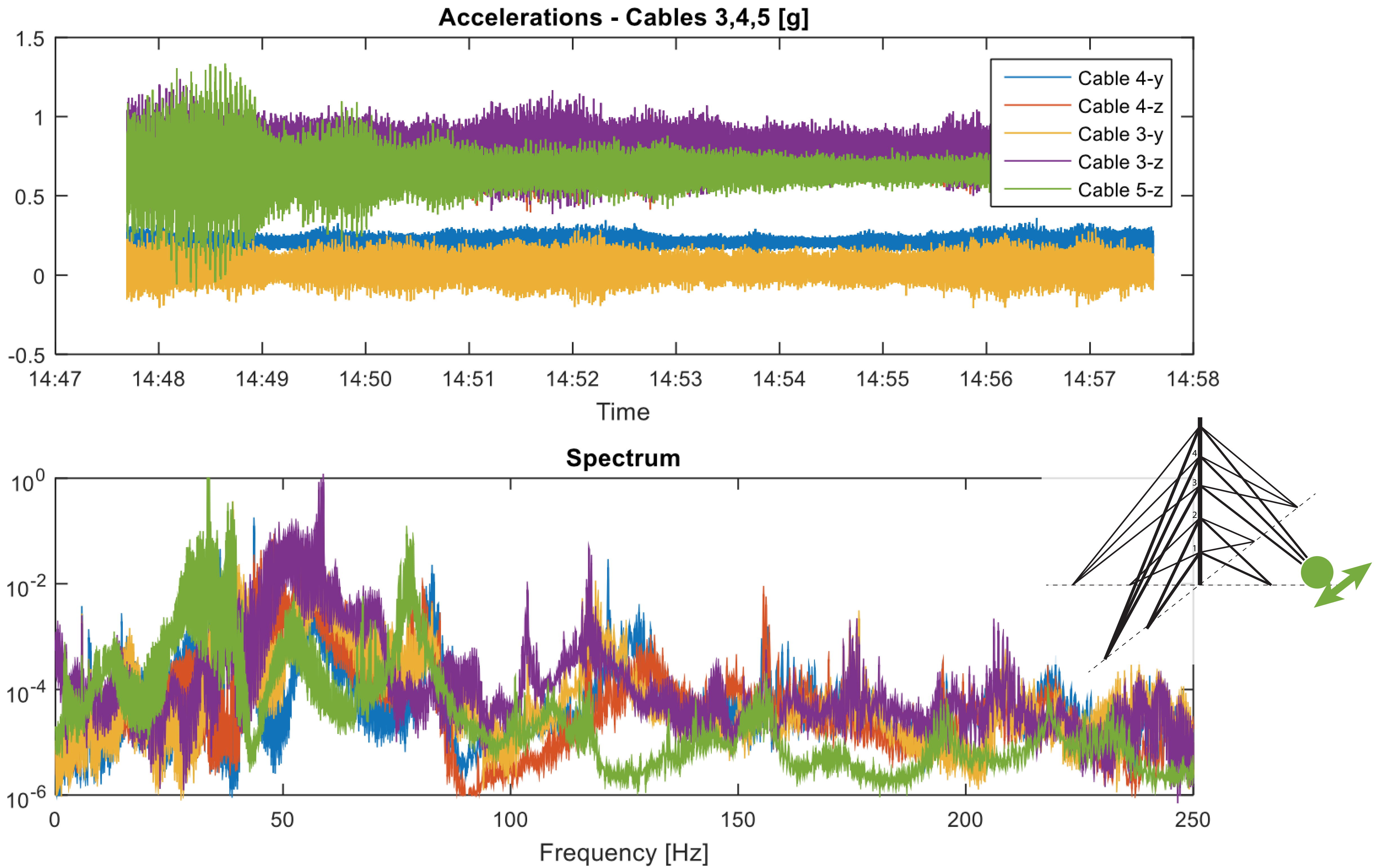






Measured accelerations on the cable

With VIV

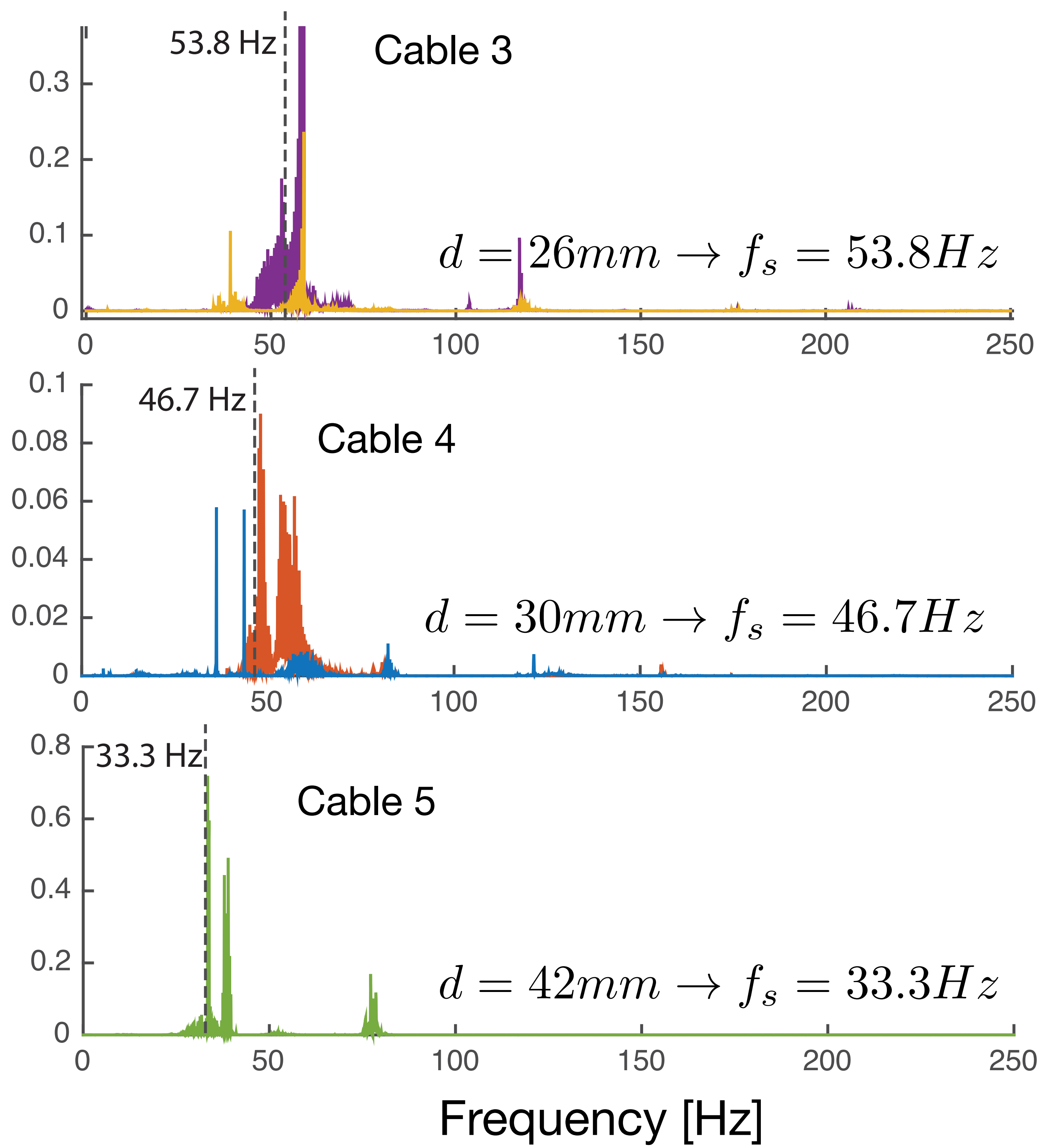


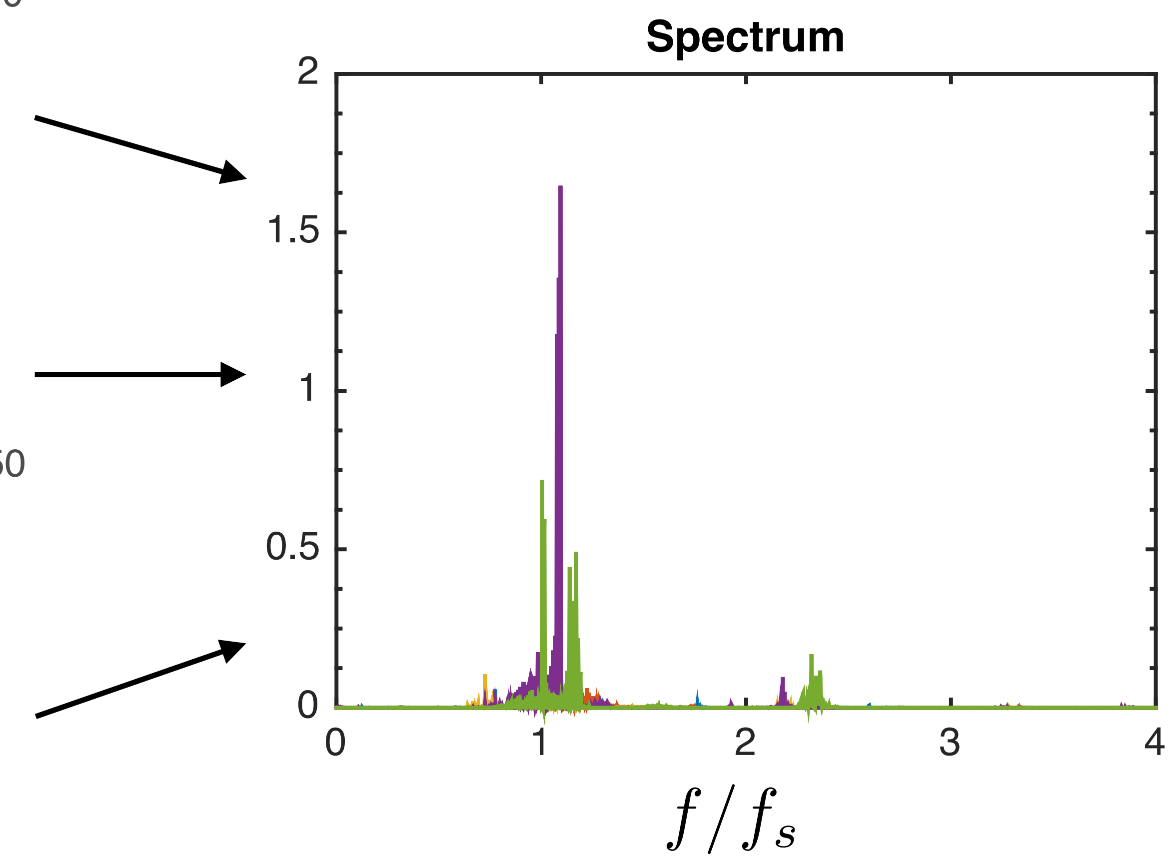
Measured accelerations on the cable

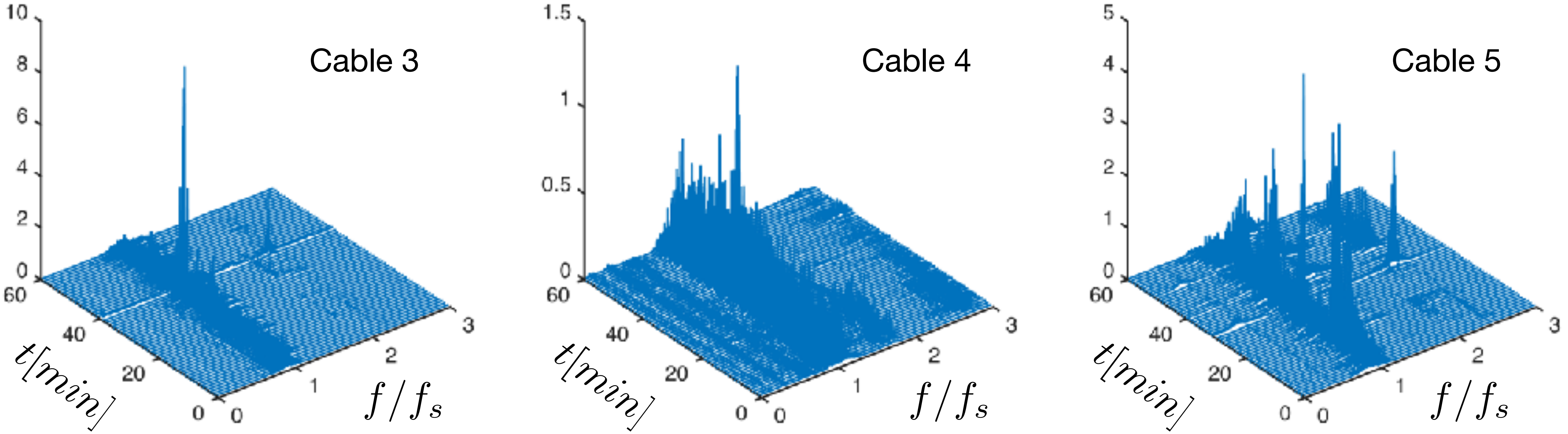
With VIV

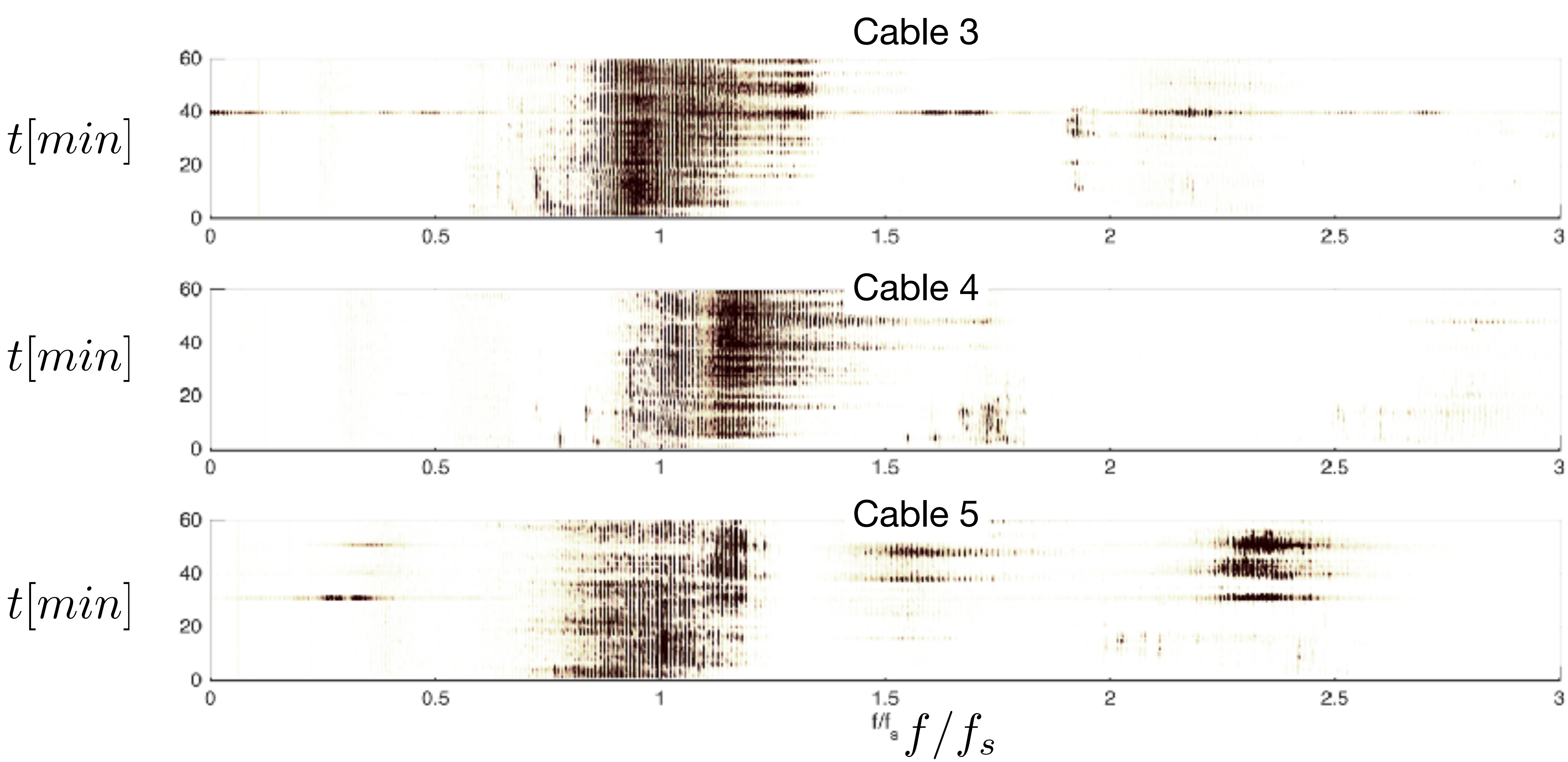
$$f_s = \frac{U St}{D}$$

$$U = 7m/s \quad St = 0.2$$





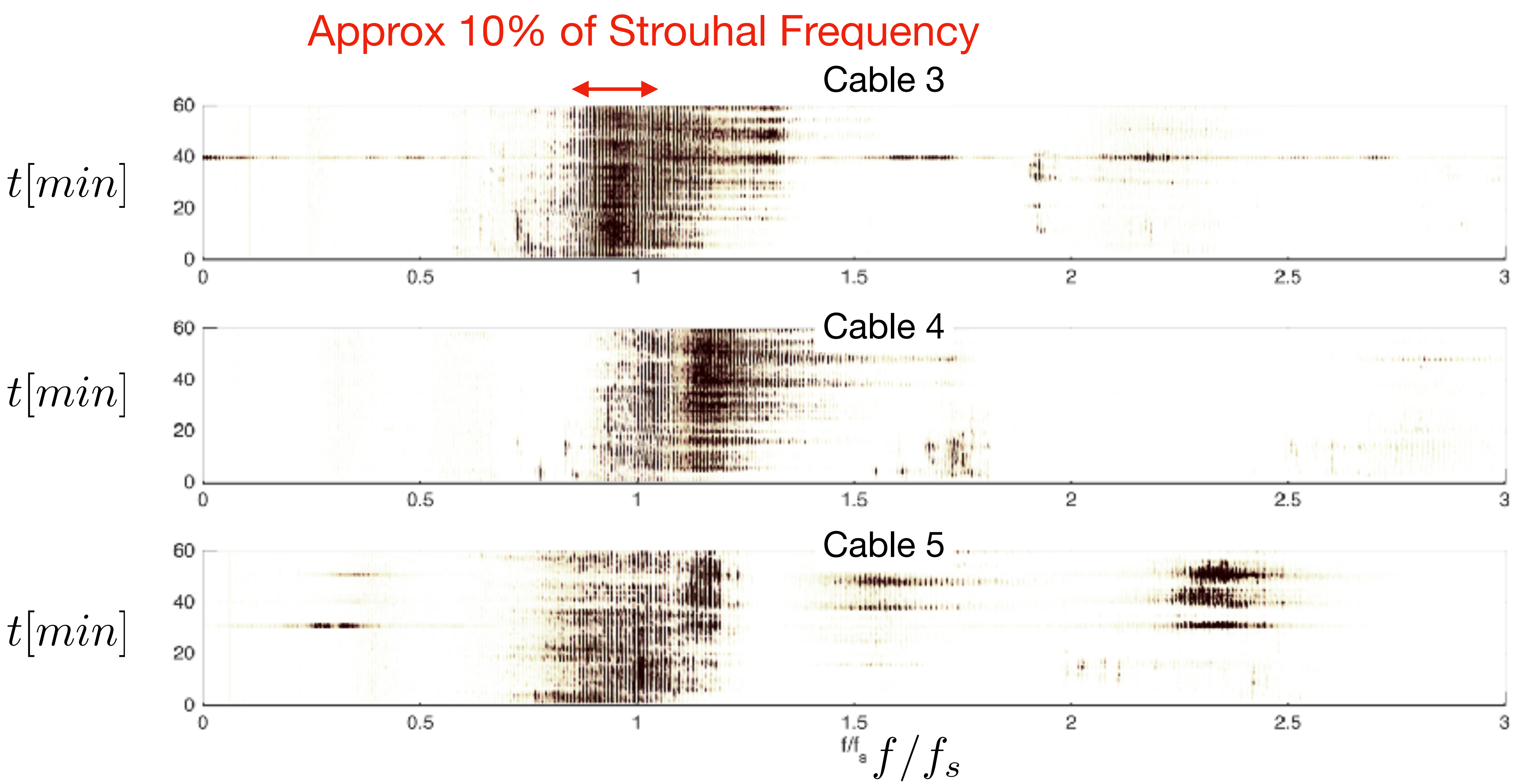

Cable 3
Cable 4
Cable 5
t[min]
f / f_s


Cable 3
Cable 4
Cable 5
t[min]
f/f_s
f / f_s

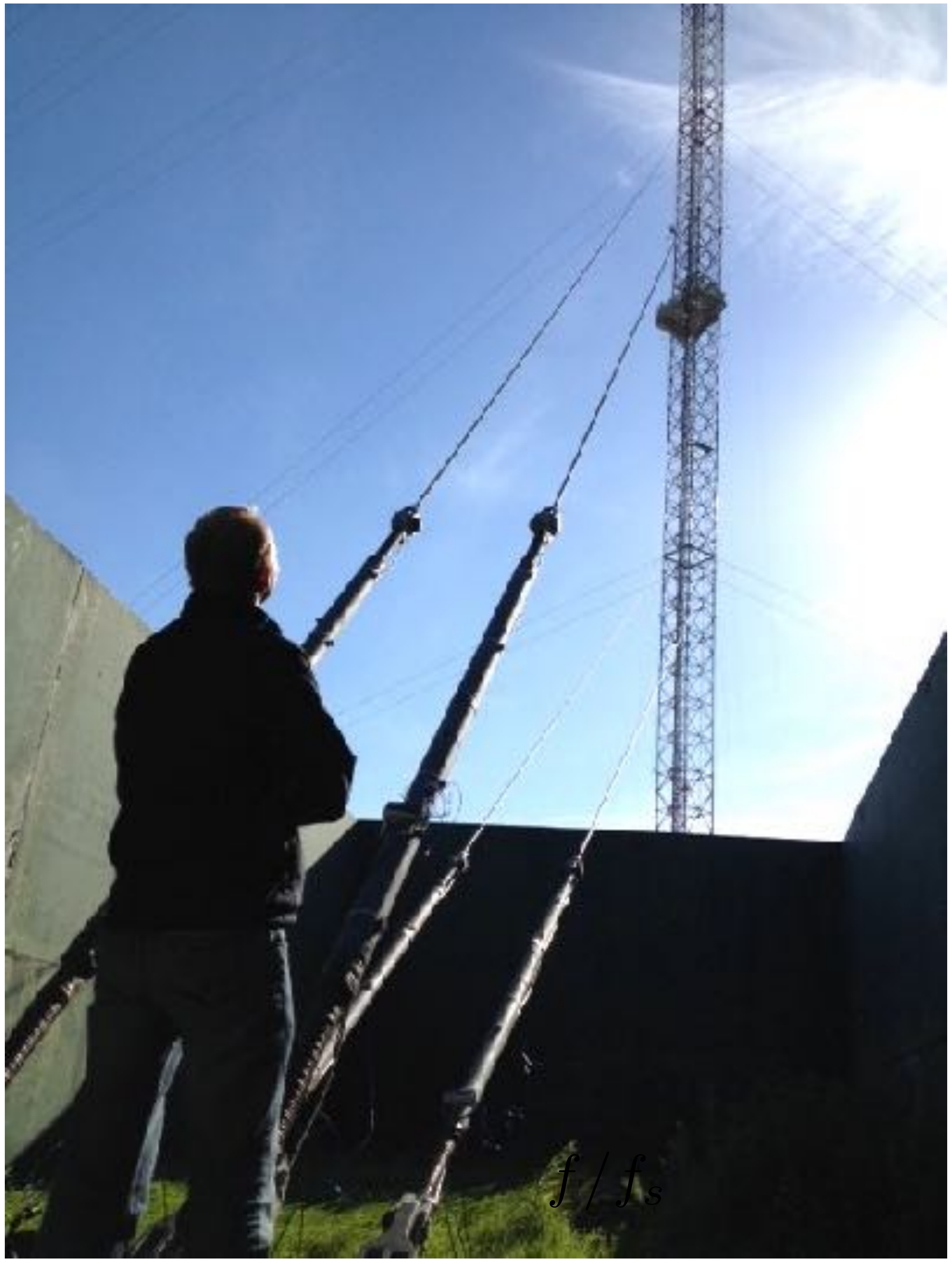
The Spectral Model

$$S_L(f,z) = \left(\frac{1}{2}\rho \underbrace{C_L}_{\text{lift}} \underbrace{D(z)}_{\text{diameter}} U^2(z)\right)^2 \frac{1}{\sqrt{\pi}\underbrace{B(z)}_{\text{bandwidth}}\underbrace{f_s(z)}_{\text{Strouhal frequency}}} \exp\left[-\frac{1}{B^2(z)}\left(1-\frac{f}{f_s(z)}\right)^2\right]$$

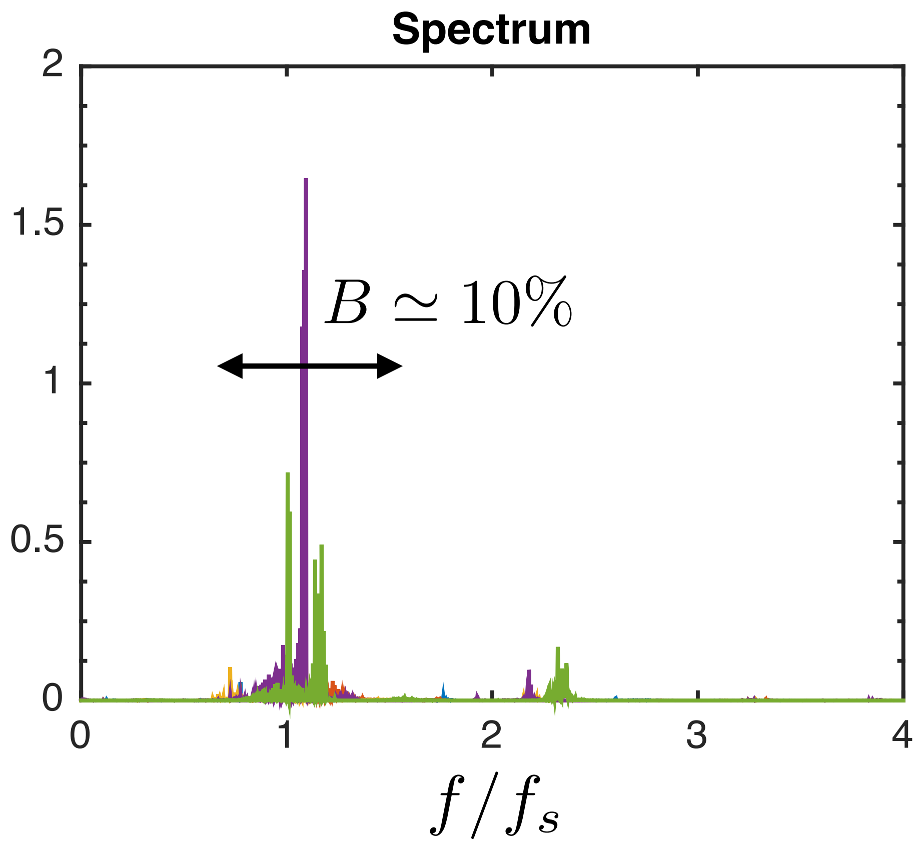
Spectral model by B. J. Vickery and A. W. Clark (1972)



Summary



- VIV observed on 3 cables with different diameters —> confirms scaling
- Consistent with the spectral bandwidth parameter
- Long cables are the perfect « observer »



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