Excitation/transfer separation in non-stationary conditions

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1. Context

- Objective : Extend blind identification method based on cepstrum to signals recorded in varying speed conditions.
- Interest : Estimate quickly the transfer function of a system (as for example gearboxes) from run-up measurements.
- Method based on both time and angular domains.

2. Presentation of the method

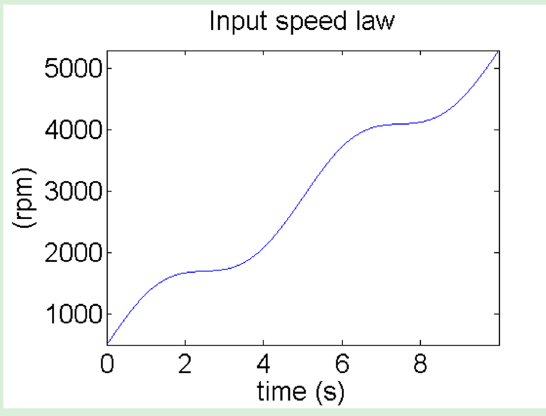
Model : $s(t) = h(t) * [d(t) + r(t)]$

with $d(t) = \sum_k c_k(\dot{\theta}) e^{j2\pi k \frac{\theta(t)}{\Theta}}$

$\dot{\theta}(t) = A\sin(2\pi f_s t) + B(t) + C$

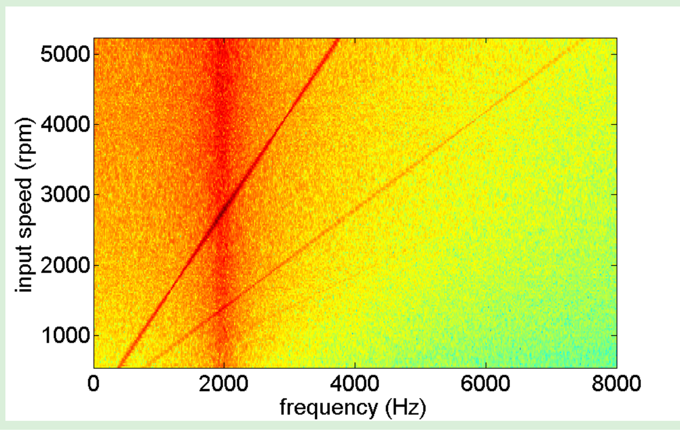
$h(t) = e^{-\zeta t}\sin(2\pi f_0 t), t \geq 0$

$r(t)$ white noise

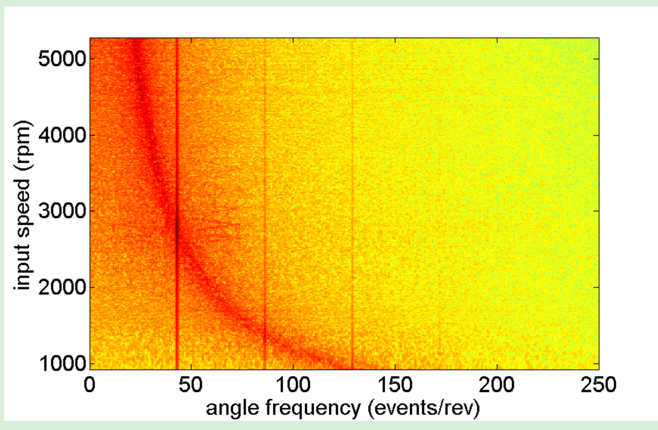


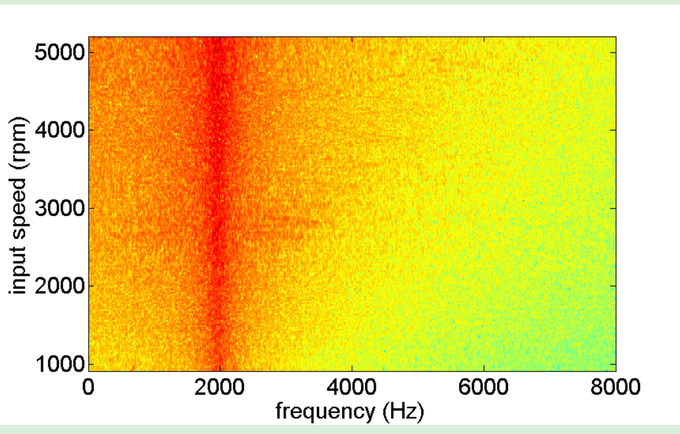
- **1st step : Extraction of the deterministic part**

Campbell diagrams :



Angular resampling



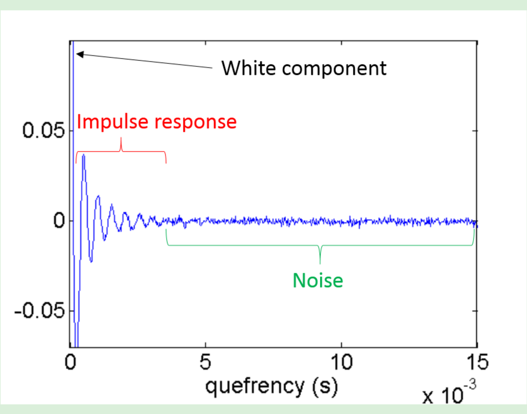


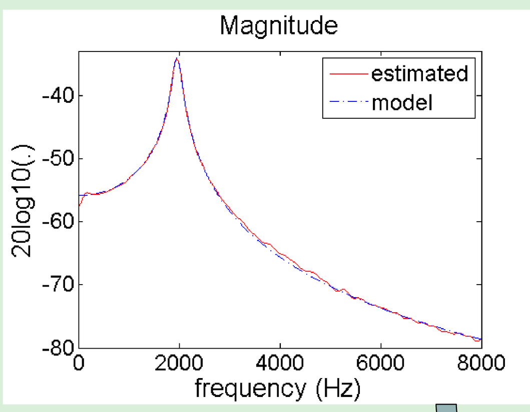
Comb filter in angular domain:

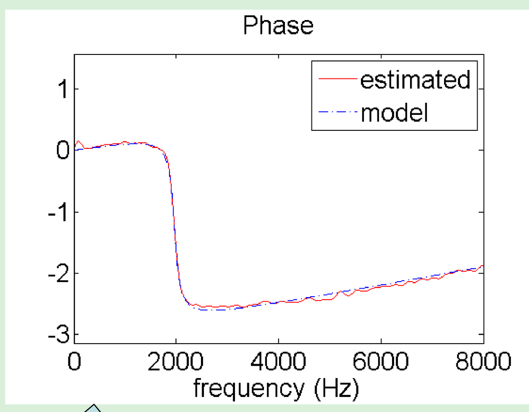
$$H_f(f_\theta) = \frac{1}{2}\left[1 + \cos\left(2\pi \frac{f_\theta}{f_0}\right)\right]^p, p > 1$$

- **2nd step : Blind identification**

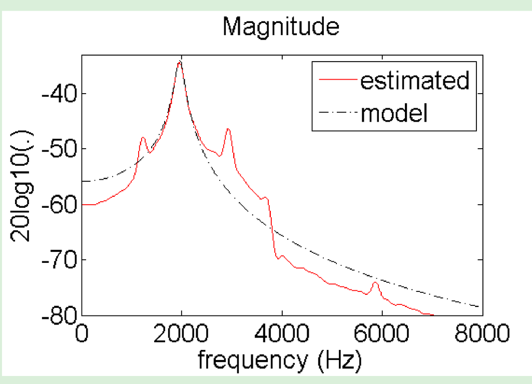
Cepstrum : $\tilde{h}(\tau) = F^{-1}[\ln|H(f)|] \Rightarrow |H(f)| = e^{F[\tilde{h}(t)]}$

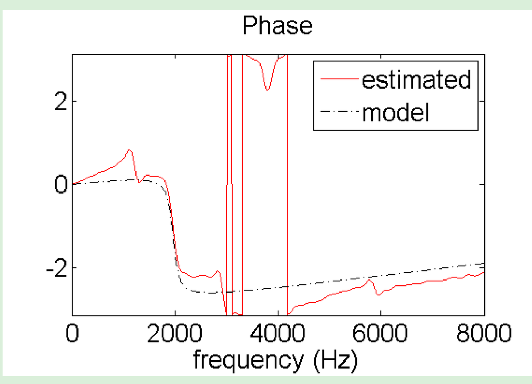






If one does not extract $d(t)$:

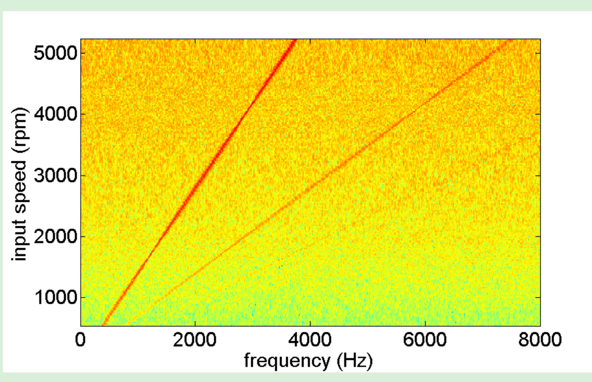




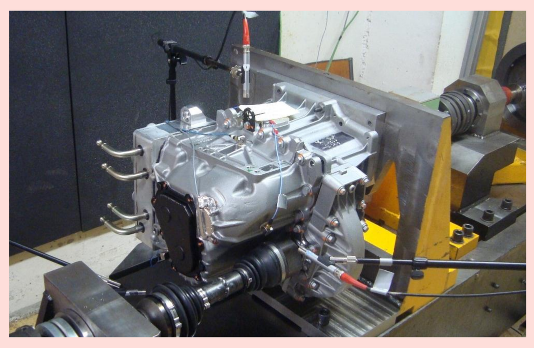
Minimum-phase assumption : $\Phi(f) = -Hilbert[\ln|H(f)|]$

- **3rd step : Whitening**

Inverse filter : $H^{-1}(f) = \frac{1}{H(f)}$



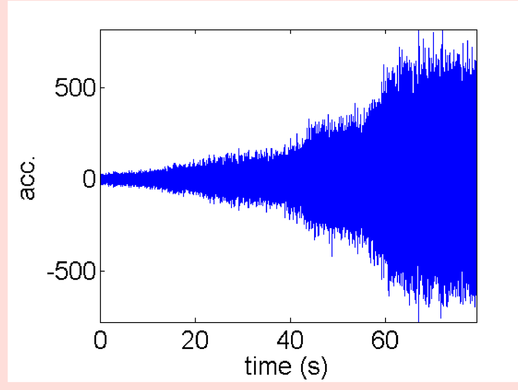
3. Application on accelerometer signal



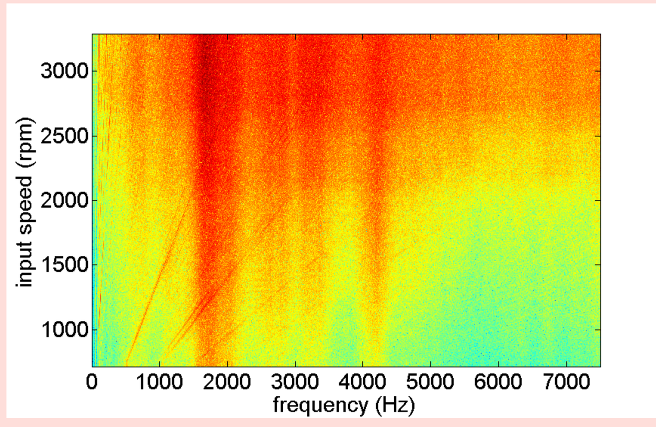
The method is applied on a gearbox vibration signal $s(t)$ with a speed ramp from 750 rpm to 3400 rpm in 79 s.

We consider $s(t)$ of the following form :

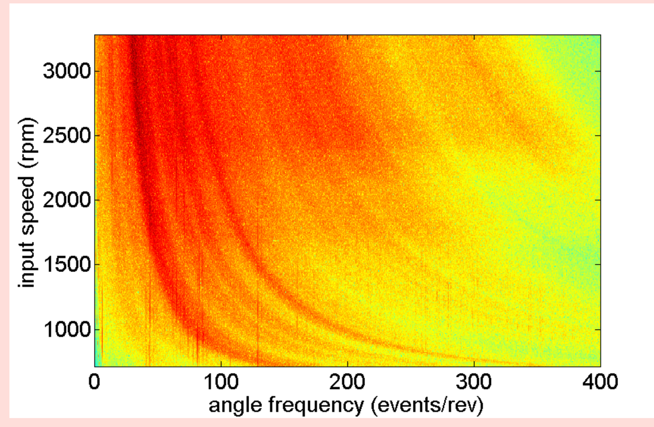
$s(t) = h(t) * [d(t) + r(t)] + n(t)$



- **Campbell diagrams :**



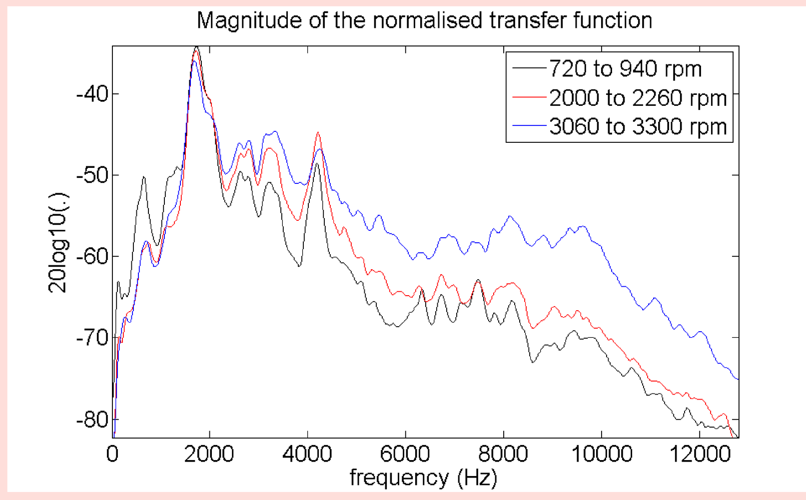
Angular Resampling with an encoder : R=60 pulses per revolution.



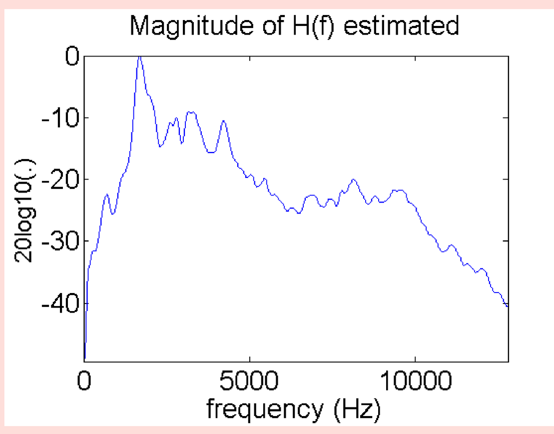
- **Blind identification with cepstrum :**

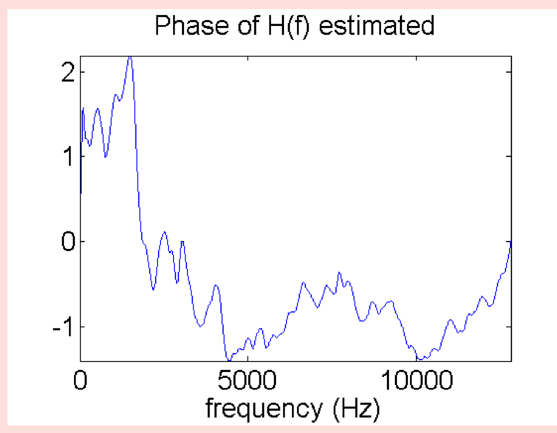
Magnitude estimated on 3 different portions of the signal

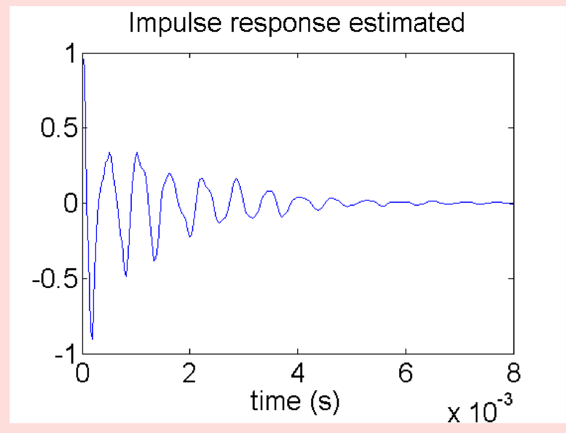
⇒Observation of the input speed influence

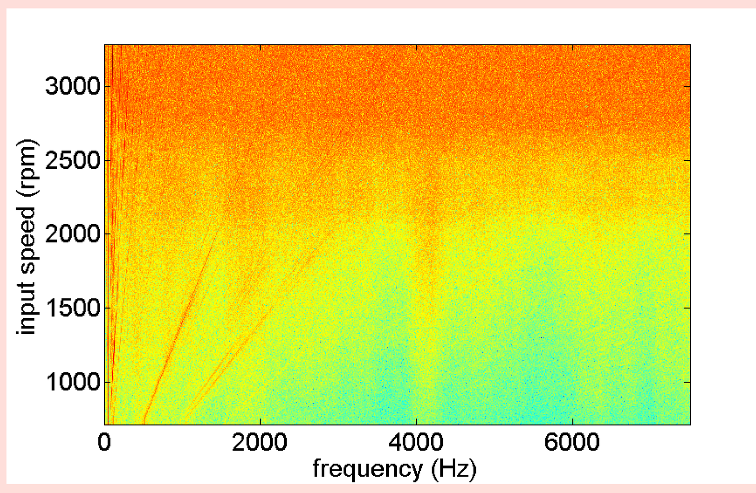


- **Whitening** with the transfer function estimated on the whole vibration signal :

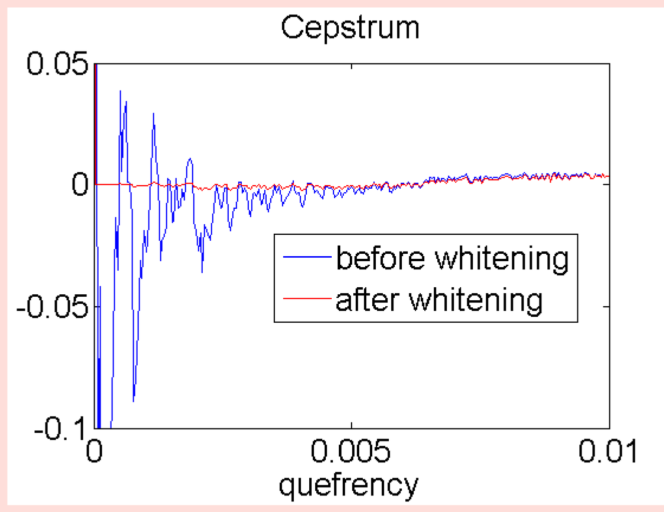








Some resonances are still remaining



=> The method can not be iterated

4. Conclusion and perspective

- Presentation of a method of separation between transfer and excitation in non-stationary conditions.
- The application on a gearbox shows that a SISO system might not be sufficiently representative.
- A Multiple Input Single Output system of the form $s(t) = \sum_i h_i(t) * r_i(t)$ could be considered as an extension.

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