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Novel Non-Contact Deformation Health Monitoring of Towers and Rotating Composite Based Wind Turbine Blades Using Interferometric Ground Based Radar

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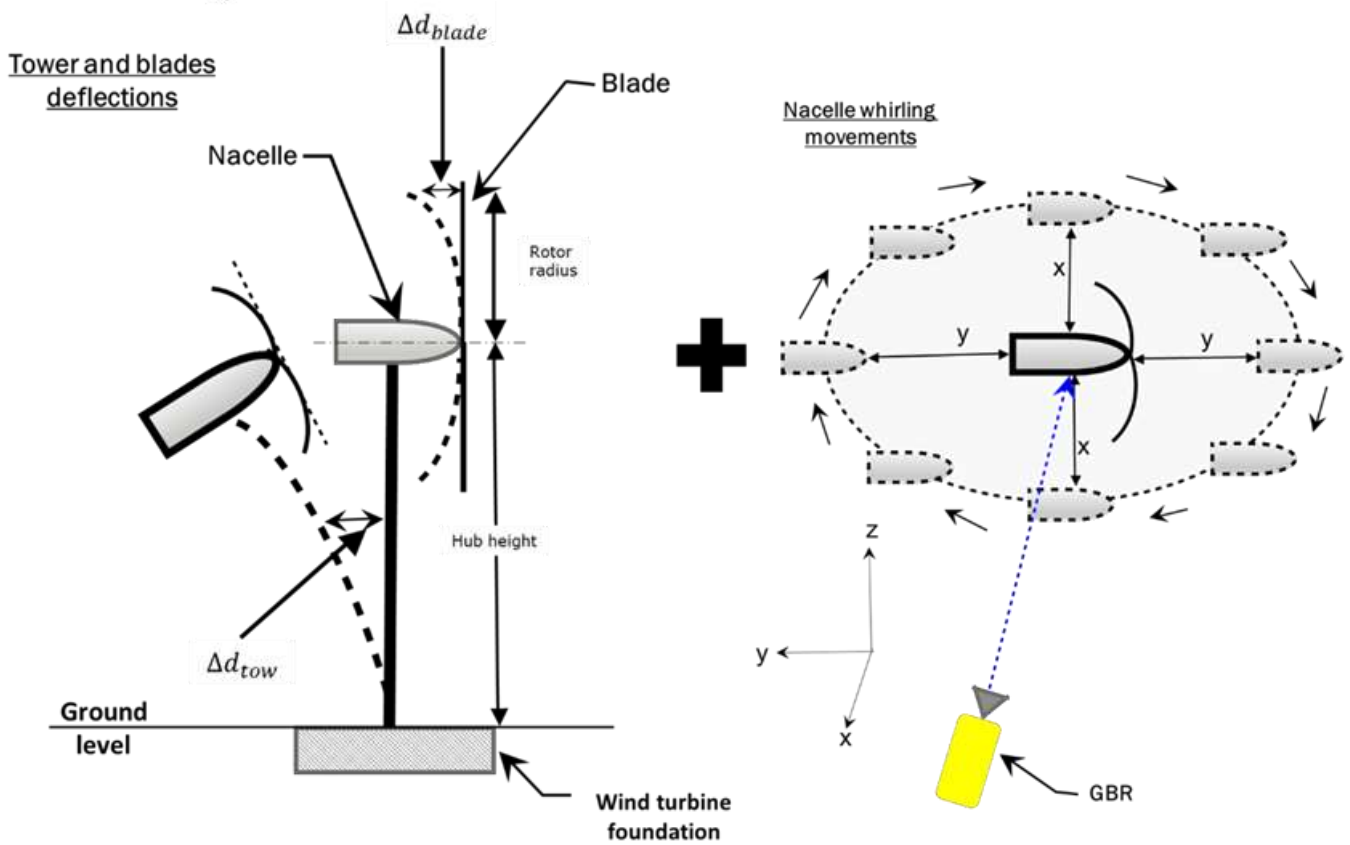
Motivation and relation to deflection monitoring



- Wind turbines (WT) are fatigue critical structures
- Challenges in
  - aeroelastic considerations
  - High lifetime design loads (>100 million cycles)
  - Use of composites in blades
  - Transients environmental & operational conditions (EoCs)
  - Contact sensors don't adequately deal with these due to placement, portability and longevity issues

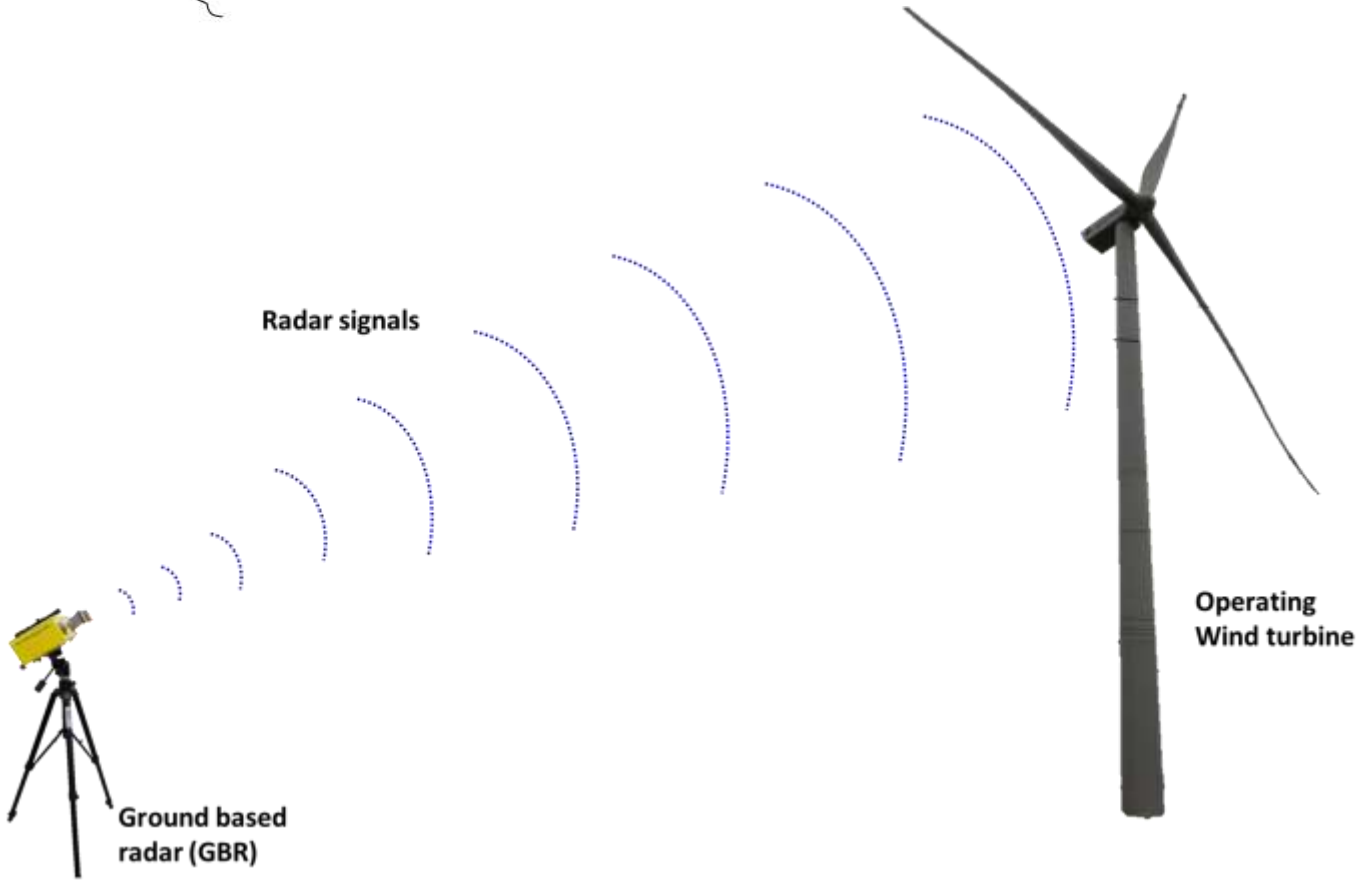
Aim of the research

- Studies using GBR have not demonstrated its use within the SHM framework
- Further the studies have not validated the acquired results with commonly used monitoring approaches in wind energy
- Aim:-
  - Determination of unbalanced parameters wind turbine blades using a non-contact GBR.
  - Application of a GBR in a 3-tier SHM framework
- Impact:- Use of GBR as a non-contact sensor to improve SHM frameworks for rotary structures like wind turbines, rotating arms

Measurement Instrument

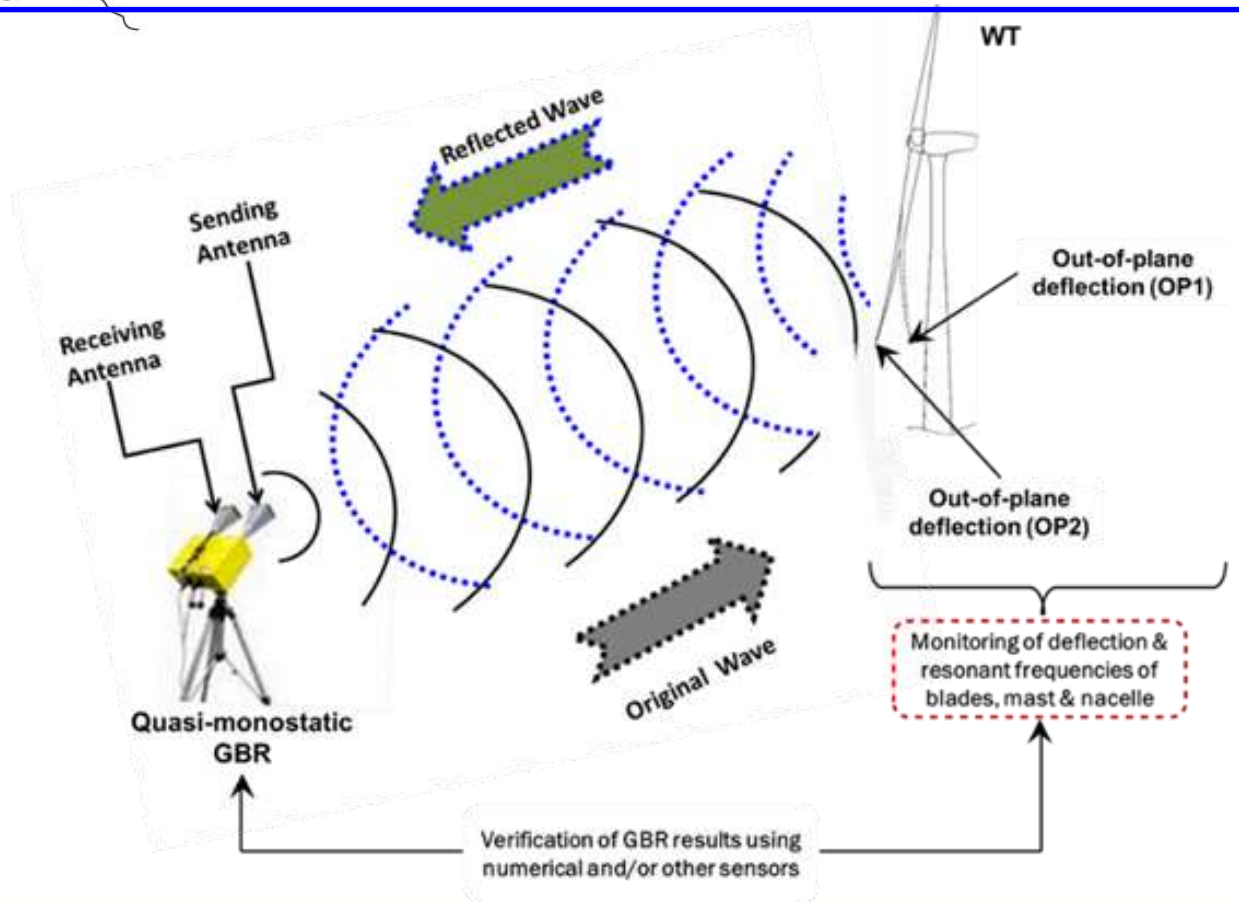
Characteristic	Value / Range
Deflection accuracy	0.01 - 0.1 mm
operating range	1km
Range resolution at 200 MHz	0.5 m
Acquisition frequency	200 Hz
EIRP power	26 dBm
Modulation / frequency band	SFCW (17.05 – 17.35 GHz)

Methodology



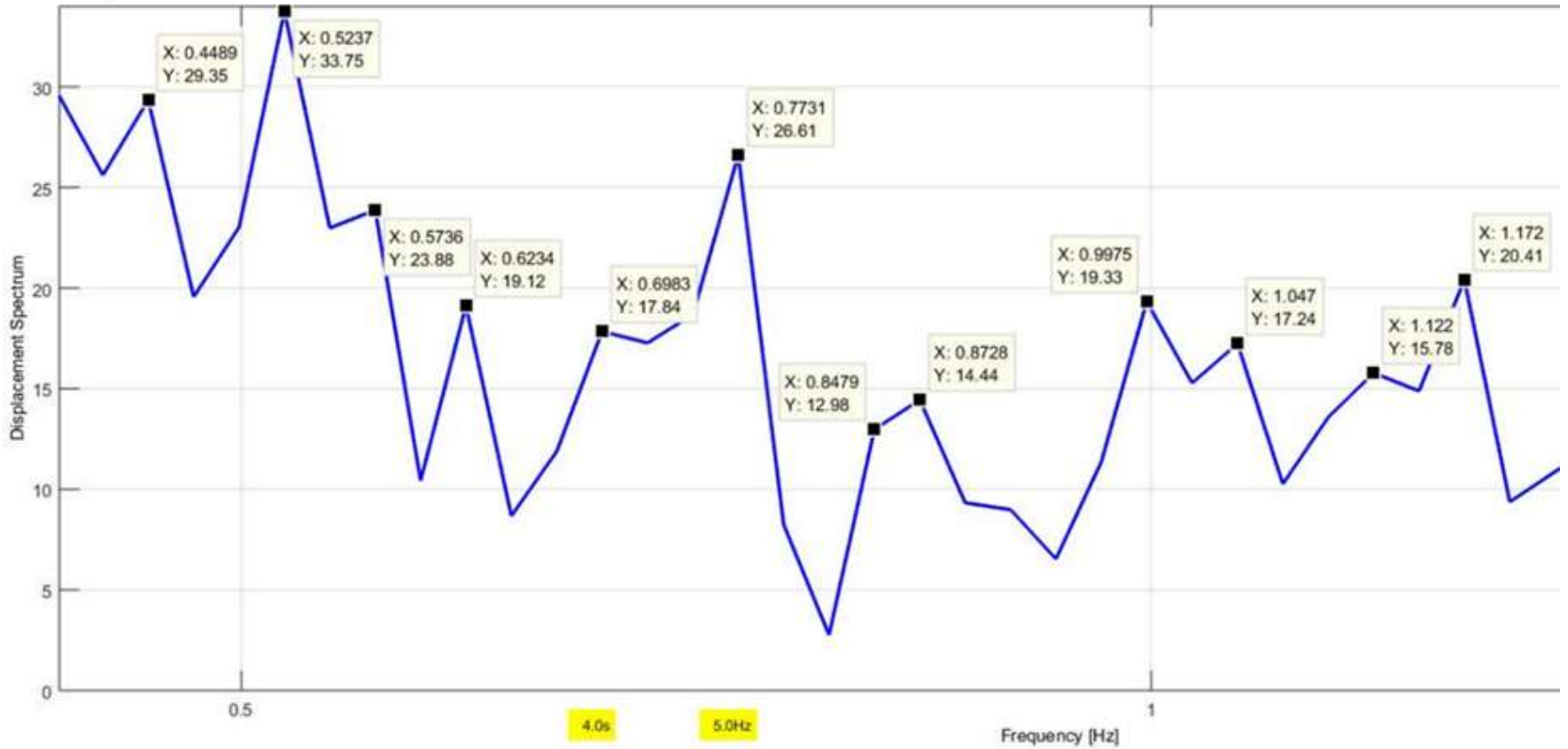
- GBR placed orthogonally to the Wind turbine
- GBR sends Ku band radio waves and receives the echoed returns
- Data analysed using Chen's and Sammon mapping
- Validation done using unbalanced parameters acquired during design of wind turbine

Results (1) : 1st Tier – Data acquisition & normalization



- GBR sends Ku band radio waves
- Bandwidth = 200MHz
- Max. range = 1 – 4 km depending on GBR type
- May require the use of additional sensors like Ground based Radar (GBR)

Results (2) : 2nd Tier – Features extraction



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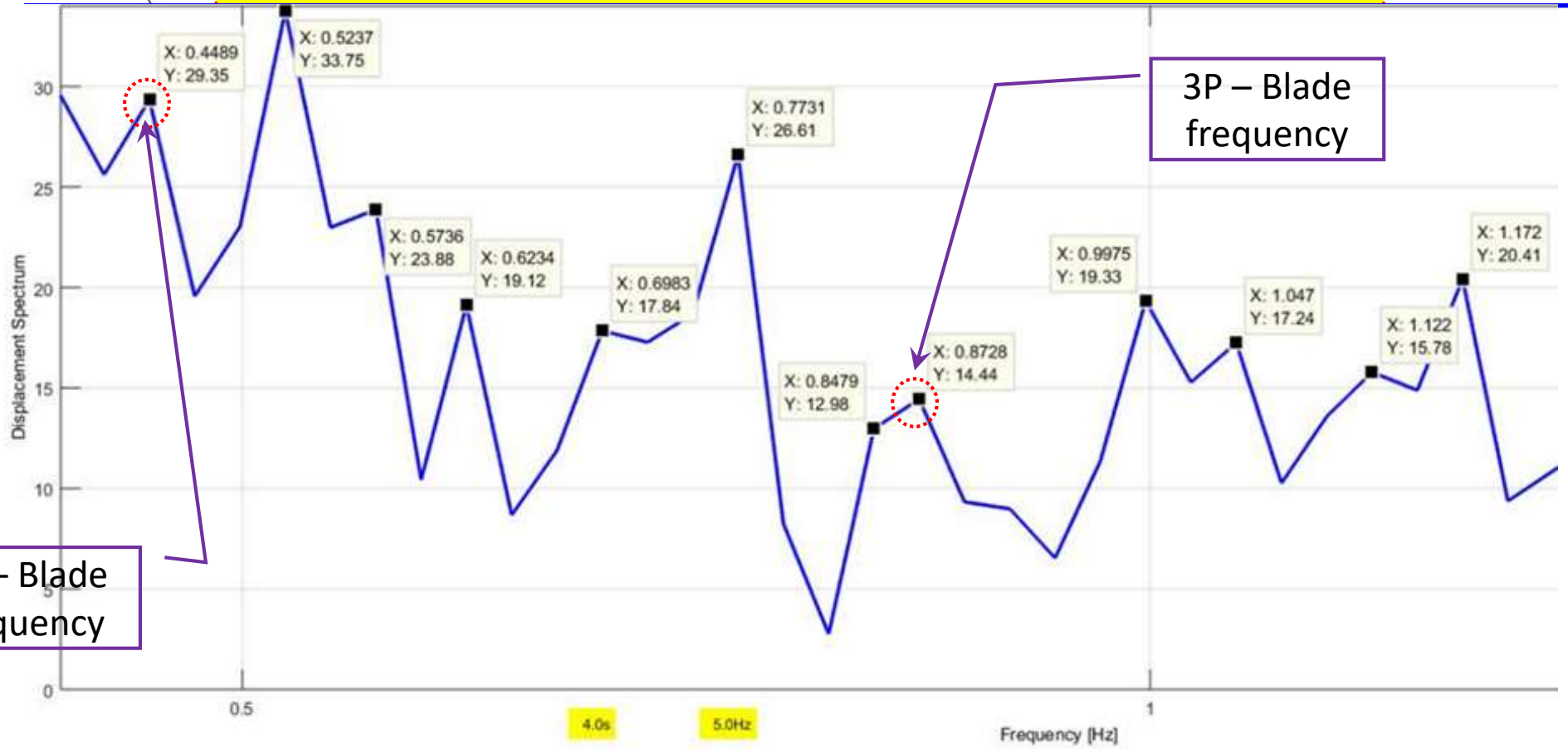
Results (2) : 2nd Tier – Features extraction (modal frequencies)

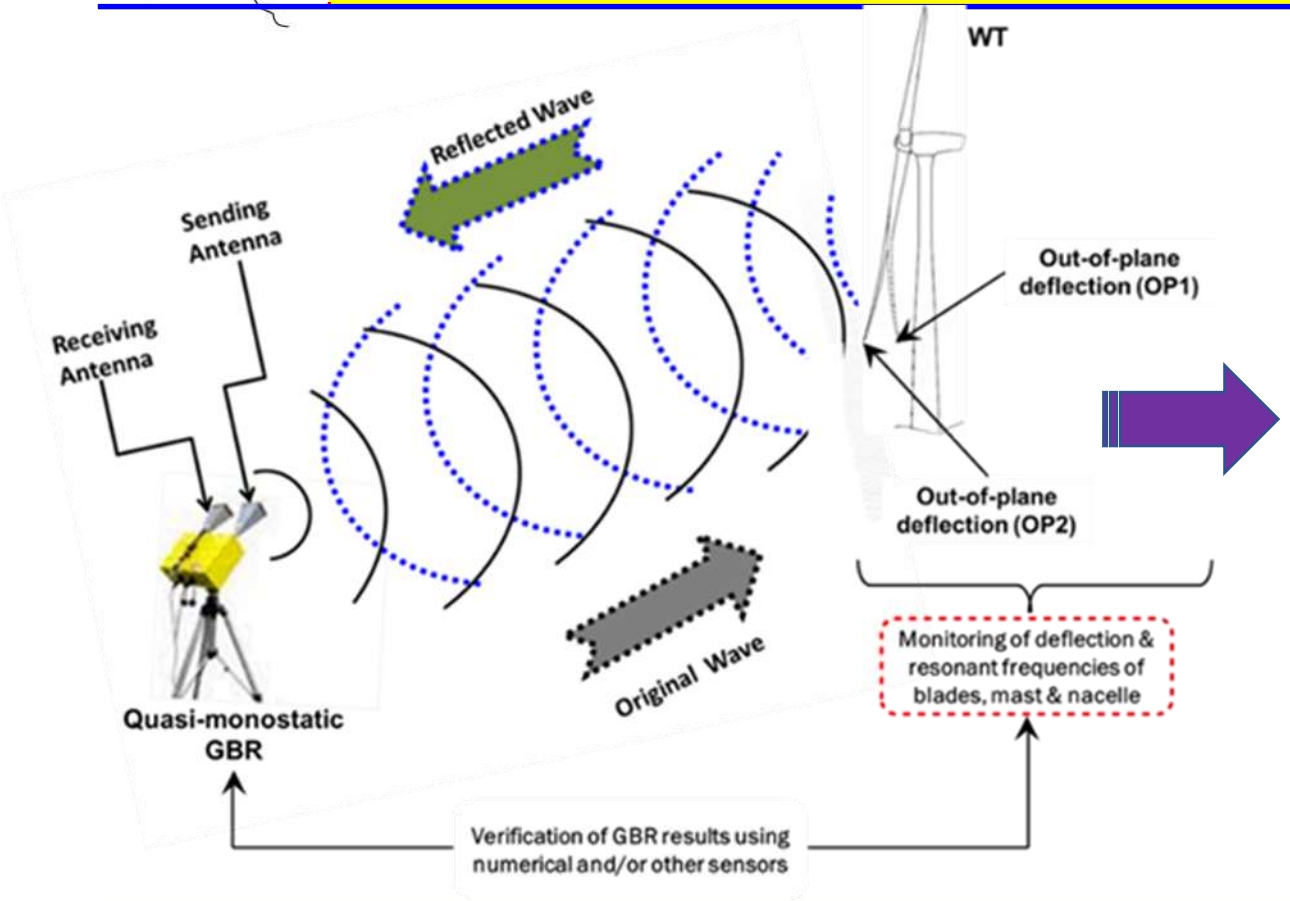


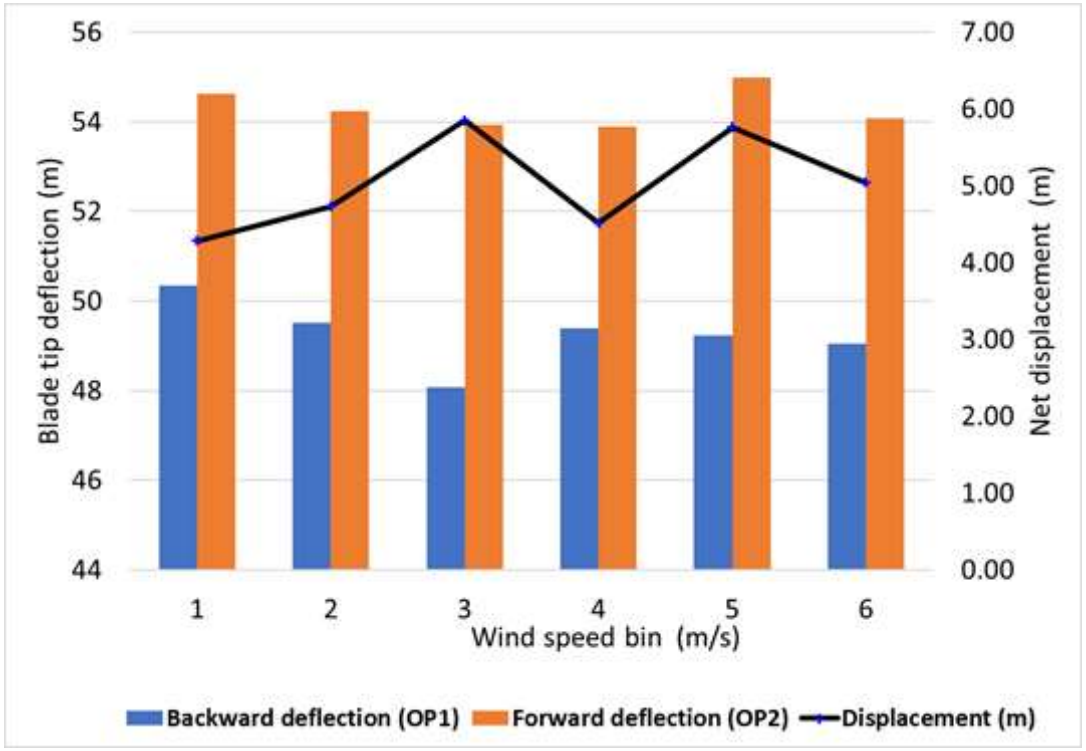
3P – Blade frequency

1P – Blade frequency

- Dimensionality reduction achieved through Sammons mapping
- Frequencies are acquired
- By comparisons with design frequencies, the resonant frequency for tower and blade can be identified

Results (3) : 2nd tier – Features extraction (Blade tip deflection)





Results (3) : 3rd – Healthy state determination & conclusion

Condition parameters	GBR measurement (±5%)	Design / Simulation (±5%)
Blade deflection	5.03 ± 5% meters	Should not exceed 10.5 ±5% meters
Blade resonant frequencies (1P)	0.4489 Hz	0.45±5%Hz
Blade resonant frequencies (3P)	0.8728 HZ	0.88±5%Hz

Conclusion:

- SHM of typical and atypical unbalanced parameters in rotating in-field wind turbines is possible with a non-contact GBR as sensor for assessing of vibrations for better structural understanding
- GBR can be used as an integral part of the 3-tier SHM framework
- Acquisition of unbalanced parameters takes less than 5 minutes.

Thank you for your attention !!