ACOUSTICS OF INFRASOUND AND AUDIBLE NOISE INSIDE HOMES NEAR WIND TURBINES USING MULTICHANNEL SPECTRAL PROCESSING

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1 Introduction

Previous measurements inside homes show presence of BPF's (Blade Pass Frequencies) below 10Hz as far away as 120km from the nearest Wind Turbine, Figure 2. This holds true for measurements inside homes, yet outside measurements become more challenging at all frequencies due to Wind Turbulence. Random wind turbulence occurs at the microphone screening devices as well as adjacent structures predominantly at lower frequencies. The homes, both near and far, act as windscreens in these low frequency settings, un-masking the BPFs that appear inside. This paper discusses both near and far field measurements in different locations inside homes while making simultaneous spectral measurements outside.

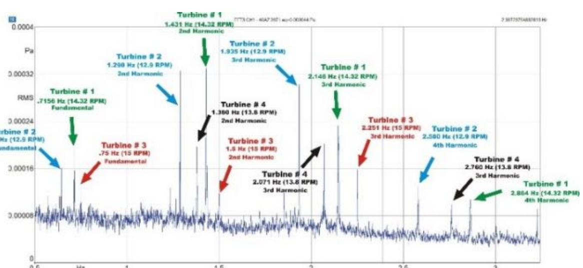

Figure 1 Spectra measured in a home over 100km away from the nearest WT show four different WTs each with three harmonics.

2 Measurements and data analysis

Two Sinus Soundbooks and two SINUS Apollo 4-analysers were deployed at times in four separate homes synchronized to the nearest second. An advanced 8-channel set up is outlined in Figure 2 Synchronous Audio and Video were also recorded for ease of analysis during playback. In one case four homes were measuring continuously in Real-time for three months. The long data sets were required since conditions for ideal weather played an important role. The homes were also occupied so contamination from human artifacts such as door slams had to be verified and eliminated. The 24-hour SONOGRAM plot validated good project days vs. contaminated days, or days without wind. All four systems were also monitored and controlled via the Internet. This validated our process and setup. It gave us the confidence that good measurements were being made and recorded continuously. Refining set-ups based on the previous weeks results allowed us to continuously optimize the set-ups therefore no further post processing was required.

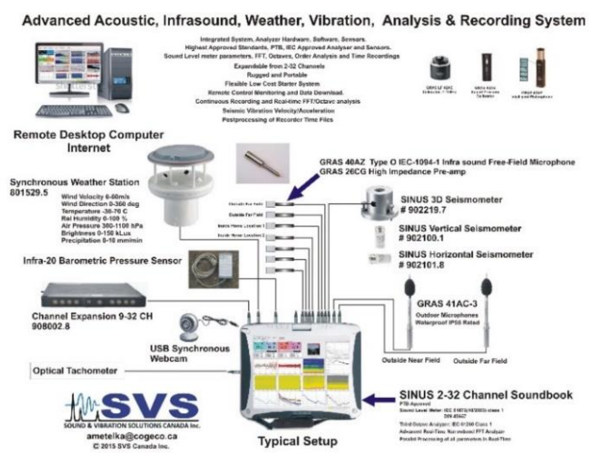

Figure 2: Advanced set-up, SINUS Soundbook with SAMURAI software GRAS 40AZ, This sensor weather station, USB Webcam.

Both outside and inside, GRAS 40AZ-Type I Precision Measurement microphones were used. The analyzer also had a LF cutoff of less than 0.5Hz. The analyzer sampling rate was 200Hz/channel, however SLM parameters up to 20kHz were also measured in these same channels using Class I IEC61672-1 filters. Special dual stage wind screens were designed, adding waterproofing to the GRAS 40AZ laboratory grade microphones for continuous use even during the winter. GRAS 42AG, 42AE and 42AE Low Frequency calibrators were used. BPFs measurements outside were not as distinct during high wind conditions compared to low wind conditions. Ideal times where during high wind shear or low ground wind speed even below 2 M/s for these outside locations.

In most cases the inside BPFs were identical and sometimes even slightly higher at the fundamental and 2nd, 3rd, and 4th Harmonic of BP. The basement room furthest from the dominant WT aimed at the home had the least amount of infrasound. The outside far-field microphone, closest to the WT in Figure 3 shows the effects of wind turbulence masking the BPFs.

In the extreme far field various WTs can sometimes be measured,[1, 2] however only inside homes not disturbed by airflow turbulence. These spectral peaks were correlated with wind direction from the SW and only occurred with steady winds. The peaks disappeared when Southern Ontario experienced no wind or wind power production.

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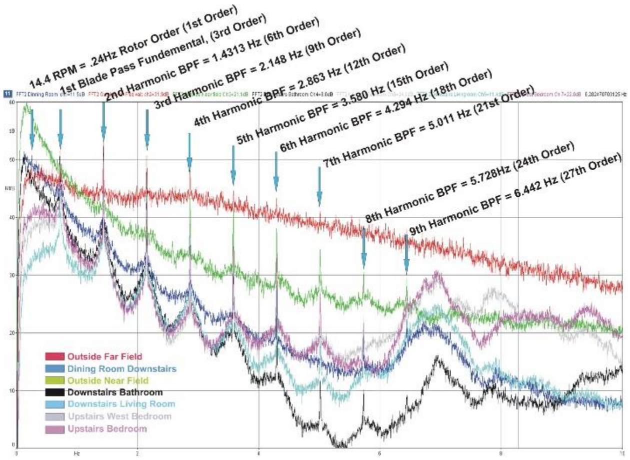

Figure 3: Spectra of 2 outdoor and 4 indoor compared. Close to 10 WTs with-in 1 km.

3 Post-processing

Further post-processing using statistically averaged cross properties such as the COH, TF and COP were deployed for various reasons [3]. The elimination of uncorrelated noise (outside) and the linear relationship between the outdoor BPFs and indoor BPFs were validated. The example in Fig 3 shows a perfect Coherence of 1 at the first 4 BPFs. This is not always the case since other artifacts can occur contaminating the statistical average.

Coherence using this FFT Analyzer can be defined as:

$$C_{xy}(f) = \frac{|G_{xy}(f)|^2}{G_{xx}(f)G_{yy}(f)}$$

where, $G_{xy}(f)$ is the Cross-spectral density between x and y $G_{xx}(f)$ and $G_{yy}(f)$ the autospectral density of x and y respectively. Although Figure 4 was post processed it could also have been setup for real-time analysis allowing faster review of many results. It also serves as a good real-time quality indicator such that the system is operating correctly without sensor error.

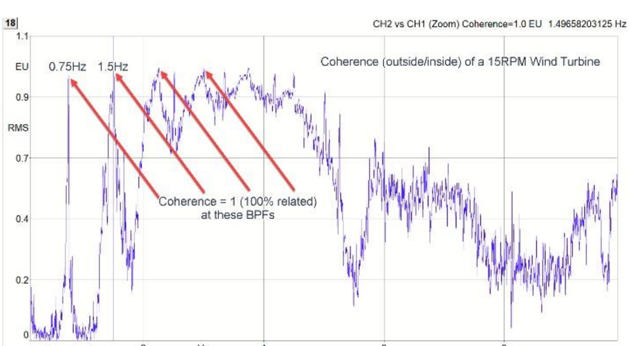

Figure 4: Coherence after 1000 statistical averages indicate 100% relationship between the indoor and outdoor WT BPFs.

Sensitive receptors have had symptoms as far a 10km away from WTs under certain conditions. Figure 5. had a single WT less than 500 meters from a home, turn into the direction where the home was downwind. The occupant felt change immediately in the case without visualizing the WT and faster than the FFT processing could validate.

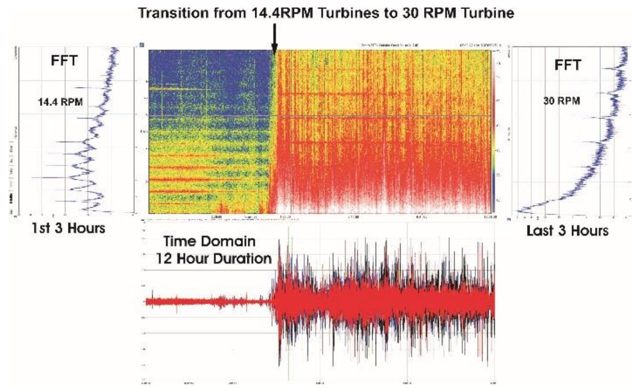

Figure 5: A single WT turns on and faces a home masking the far field 14.4 RPM turbines.

4 Summary

Measurements inside, being free from wind turbulence, indicate BPF's are clear and distinct at all times of day and year. The BPFs only appear with wind and power production. The home can act as an ideal random infrasonic turbulent resistant windscreen. This allows for further calculations such as transmissibility in each location inside a home with a laboratory grade infrasound measurement microphone. The measurements indicate it is not what you hear; it is what you may feel inside quiet rural homes that are free from Random Dynamic Pressure fluctuations between 0.5-3 Hz where the fundamental and 3 harmonics of WT BPFs become periodic.

Acknowledgment

There are too many international associates to thank and recognize over the years however, Dr. John Vanderkooy and Dr. Werner Richarz are the Canadian professors involved with the physics, science, acoustics and instrumentation.

References

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[2] Measurement Techniques for determining Wind Turbine Infrasound Penetration into Homes 7th International Meeting on Wind Turbine Noise, Rotterdam, the Netherlands, 2nd – 5th May 2017 Andy Metelka, SVS Canada Inc, Canada

[3] J. Vanderkooy and R. Mann, "Measuring Wind Turbine Coherent Infrasound", 6th International Conference on Wind Turbine Noise (WTN2015), Glasgow 20-23 April 2015.


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