There seems to have been confusion in the Acoustics Industry concerning recording the infrasound (and partly audible) "noise" pulses (the highest amplitude part of the pulse is below the hearing frequencies) from a cluster of Industrial Wind Turbines (IWTs), since the first time-domain pictures of low frequency air pulses were published by Kelley et al at NASA in 1985 and by Shepherd et al at NASA in 1989. The IWT is basically like a seismic airgun and the cluster of turbines is actually a source-array. A source-array is used to cancel the horizontally travelling pulses and waves. The IWT cluster is not a very good source-array, but does create some cancellation of the air pulses due to the slightly variable pulse-firing rates (same as the blade pass frequency or BPF) within the IWT cluster and the inclusion of reflected pulses. However, there are also constructive pulses that are created regularly at various geometric positions around the IWT cluster, depending on wind direction and other atmospheric and surface conditions. These constructive pulses can be several times larger than a pulse from a single IWT and they occur about 10% of the time (2 or 3 big pulses every 30 seconds, for example) around the exterior of a typical IWT cluster in residential areas. These are the low-frequency air pulses that can activate the nausea/dizziness/nervous reaction by impact and vibration of some of the parts of the ear.

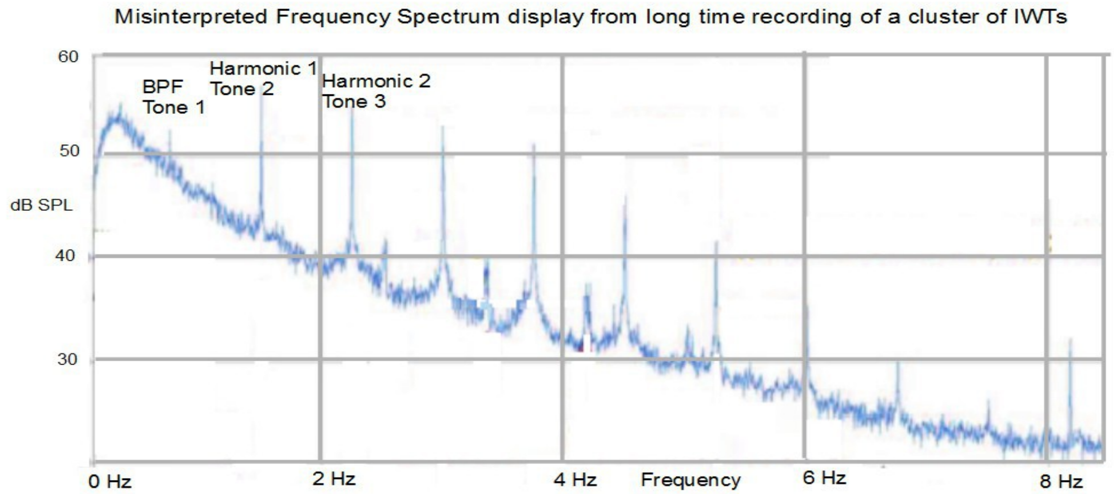
Frequency Spectrum displays have been created in some publications that I believe are displays of "artifacts" caused by a combination of various procedures in the data processing sequence that are listed as "application of a Fourier Transform" while creating a Frequency Spectrum display. Some methods involve summation or "stacking" of frequency spectra (in the complex domain) from segments of a long time recording. This is equivalent to taking segments of time from a long time series and summing them together (see references on pg. 2) which we know will cancel out much of the data that appears random in the series while enhancing data that is "coherent" (in the freq. domain the BPF is most coherent, though this is insignificant in the time-domain). This stacking of Frequency Spectra is virtually unheard of in the Seismic Data Processing industry, which is a big industry. Other methods (like Welch's method) that change the input data from its "real-time" characteristics, involve short windowing of time-data (which can smooth and omit data), and averaging of amplitude or power per frequency "bins" (more data rejection) and sometimes frequency data editing based on data-distribution quartiles (which can omit the high amplitude, low-frequency data completely). However, due to the laws of physics concerning summation of pulses within the IWT source-array, this type of "Time-accumulated Frequency Spectrum" display creates an array-response of the "spatial and time" related filter created by the slowly changing pulse-firing rates within the source-array (the IWT cluster). (see below "Misinterpreted Frequency Spectrum display from long-time recording of a cluster of IWTs). This display could possibly be labelled; "Time-accumulated Array Response of a Cluster of IWTs". The problem with creating this display is that the "Time-accumulated" domain is a fake domain. It is irrelevant to our existence and is basically meaningless. The longer the input data to the Frequency Spectrum displays, the higher are the leakage spikes (compared to the average line) on this source-array filter leakage plot. That means that it's a data "processing artifact". Some people reconstruct a time-domain pulse based on these spectral leakage spikes (frequencies at the BPF and its harmonics) using "Fourier Synthesis", which creates a synthetic pulse, but this is not really the pulse from the IWT operating above (let's say) 15 kph weather report winds, which contains all frequencies between 1 to 50 Hz. (approximately). This type of frequency plot with sculpted peaks is NOT an indication of the frequency content of the air pulses (the high-amplitude, 300 msec noise bursts) from an IWT or cluster of IWTs.

The BPF is not directly related to the frequency content of the air pulses as would be obvious if you started up the IWT and it emitted one pulse only, then "hit the brakes" and stop the rotation. There is no BPF, but the air pulse is exactly the same as those from a continuously rotating IWT.

IWT clusters in residential areas have poor array-response or "poor cancellation" of the horizontally travelling low frequency pulses and waves, due to their hap-hazard spatial layout from the use of small, leased parcels of land.

The frequency content of the low-frequency pulses looks like that in figure 9 (also shown below) of the paper, "The Industrial Wind Turbine Seismic Source", with a dominant frequency in the 4 to 16 Hz range with frequencies up to the 50 Hz range, where a small amount of noise like a "whump" can actually be heard in some locations within about 300 to 500 meters distance from the IWT. The use of microbarometers instead of microphones in recording noise from IWTs, in some of the publications by acoustics technicians found on the internet, confuses the issue of IWT pulse generation because the very, very low frequencies in the micro-barometer data (less than 1 Hz) are left in the displays, but the external sources of these frequencies is not identified so they can be removed from the discussion.

Michael West, P. Geoph, BSc, GDM., BC, Canada, June 2021



Note: This type of Frequency Spectrum display is circulating around the internet by acoustics technicians. It is misinterpreted with "tones and harmonics" labelled. The peaks are not really tones or harmonics of the dominant frequency of the IWT noise (air pulses). The peak at the so-called BPF is just the firing- rate of the pulses by the IWT. The so-called "Harmonics" are actually typical side-lobes of the array-response, or otherwise known as Gibb's Phenomenon, from the abrupt "filtering" by this time-accumulated frequency display method. The entire IWT cluster is actually a source-array that can cancel some of the air pulse energy at a given receiver point. However, the array-response is quite poor in real-time at any given location. (poor cancellation of horizontally travelling waves). By accumulating time within the creation of the Frequency Spectrum display, one creates the above display. It is merely a processing artifact. It contains meaningless information in a fake domain that is irrelevant to our existence. The above analysis has been run for many minutes or hours. Frequency analysis of noise recordings should be done on small time-windows on the order of 1/3 second or less to determine the accurate frequency content of the air pulses after perusal of the time-domain recordings.

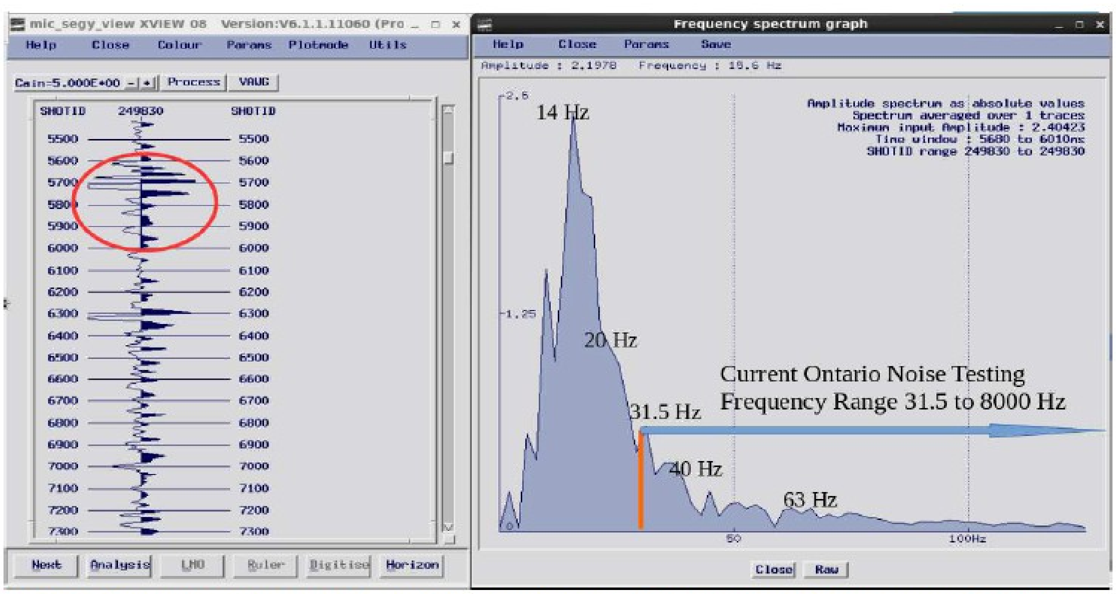


Figure 9. Fixed amplitude display of the recorded air pulse/wave time data with frequency amplitude spectrum, recorded 550 meters away from the closest of 3 IWTs operating in 20 kph (weather-report) winds. The peak amplitude at 14 Hz is approximately 2 times higher amplitude than that in the 20 Hz band, 3 times higher than the 31.5 Hz band, and 22 times higher than the 63 Hz band. Note the differences in amplitude of the 3 air pulses due to constructive interference and possibly wind speed.

References for Fourier Transforms Equivalent Operations in Time and Freq. Domains

Yilmaz, Ozdogan, 1987; Seismic Data Processing, pg. 417, Appendix A, Table A-1
Sheriff, R.E., 1981; Encyclopedic Dictionary of Exploration Geophysics, pg. 89
Or at https://wiki.seg.org/wiki/Dictionary:Fig_F-20