Cumulative Noise from FrostBoss Wind Machines

The following Cumulative Noise Prediction Model was developed in response to a need for Wind Machine operators to be able to assess the cumulative noise level of more than one FrostBoss Wind Machine operating in their neighbourhood.

The input parameters for this noise model are:

1) An accurate formula for the noise versus distance for one FrostBoss Wind Machine operating alone, on flat terrain under radiation frost conditions, and
2) A formula to determine the cumulative noise from multiple Wind Machines.

The **formula for the noise versus distance** for a single FrostBoss Wind Machine has been calculated from actual noise versus distance measurements made by two independent acousticians in Spring 2004. This formula is accurate to within 0.2 dBA for distances of 100m to 800m from the Wind Machine and is described by:

Noise Level (dBA_{L10}) = $105.1 - 8.838 \log_e D$ (D = distance from Wind Machine in m)

The **formula for the cumulative noise increment** is based on the standard acoustic principle that the addition of 2 noise sources can be calculated from the addition of their sound intensities, not the addition of their sound pressure levels.[1] Hence the cumulative noise formula for the addition of 2 noise sources is described by:

Cumulative Noise Level (dBA_{L10}) = $10 \log_{10}$ (10^[A/10] + 10^[B/10])

Where A & B are the noise levels (dBA) measured for each noise source on their own.

The above formula is correct for individual noise sources being at a constant sound pressure level. In reality, the noise output from a Wind Machine is cyclical, and the 4-Blade FrostBoss Wind Machine has a distinctive, uniform noise signature, unlike 2-blade Wind Machines that have a more random and spikey noise signature. The diagram below shows the noise signature of a FrostBoss measured 100m from the machine. The machine was running at its maximum continuously rated (MCR) power of 1700 rpm, or in motor sport terminology – it was running at "full noise".

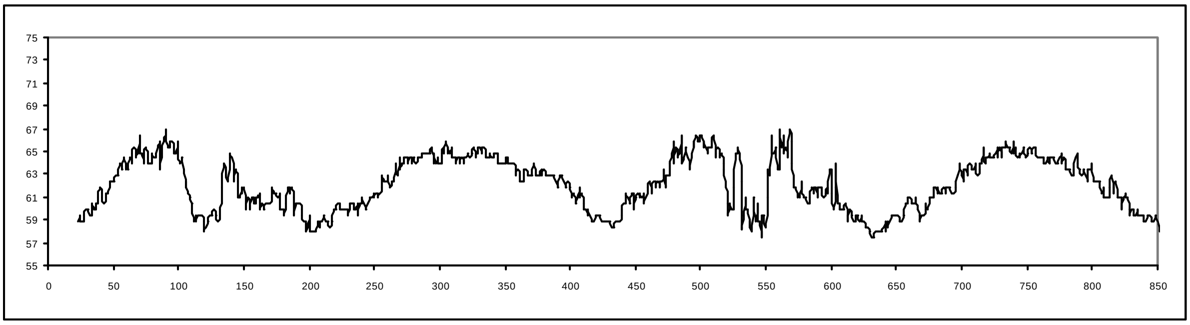

Fig.1 Noise signature over 2 complete rotation cycles (approx 840 seconds)

[1] Woods Practical Guide to Noise Control, by Ian Sharland.
Published by Woods Acoustics, UK, 1972 (Pages 7-11)

The distinctive feature of the FrostBoss noise signature is it's uniformity. The peaks correspond to when the fan is blowing towards and away from the observer, and the troughs correspond to when the fan is blowing perpendicular to the observer. The big dip in the middle of the peaks at 120 and 540 seconds occurs when the fan is hidden by the tower.

Now if two Wind Machines are running, and they are the same distance from an observer AND they are precisely in phase with each other, then by using the formula above, we would find that the cumulative noise of these two machines would result in a 3 dB increase over the noise of one of the machines running alone.

The probability of the machines running in phase, is just as likely as the machines running out of phase, where the noise peak of one machine occurs at the same time as the noise trough of the other machine. This effect is shown in Fig.2, where the red line represents the second machine running one quarter of a rotation out of phase, relative to the first machine.

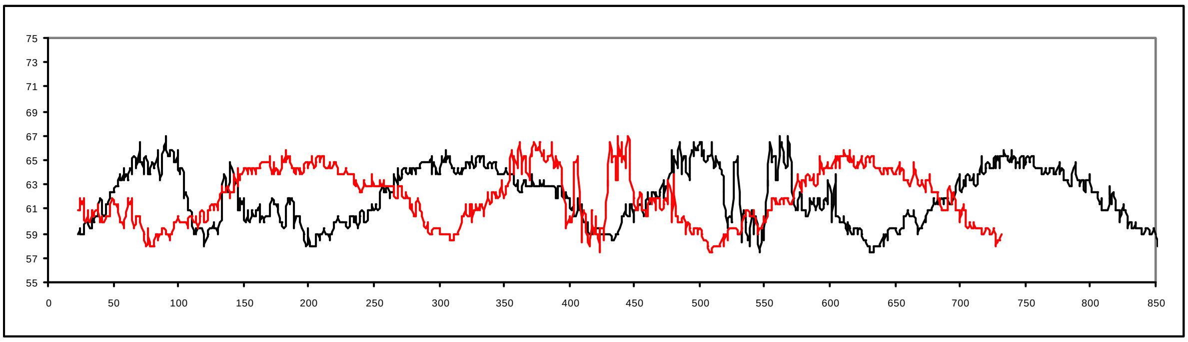

Fig.2 Noise signatures from two machines running ¼ of a rotation out of phase

By applying the cumulative noise formula to every 1-second noise reading for both machines, it is possible to calculate the instantaneous cumulative noise. This is shown as the green line in Fig. 3 below.

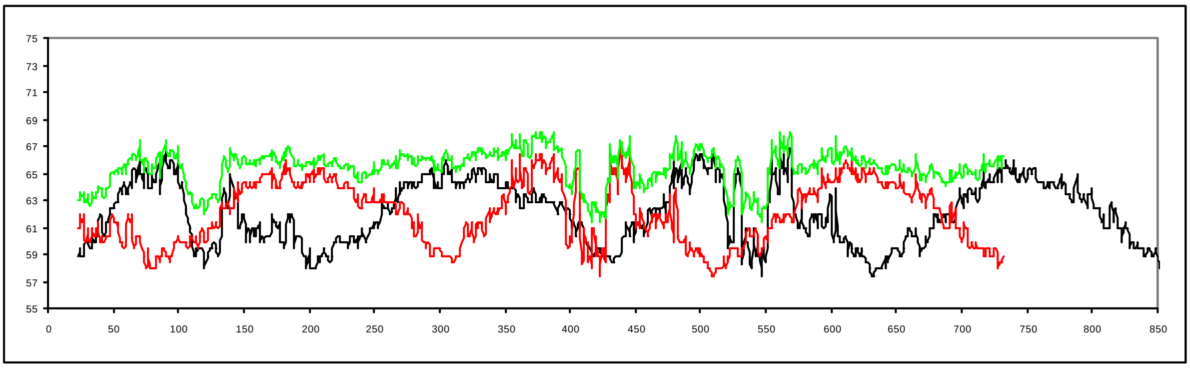

Fig.3 Cumulative noise from two machines running ¼ of a rotation out of phase

It is quite apparent that the cumulative noise increment is nowhere near 3 dB, as it would be if the machines were running in phase. In this instance, the cumulative noise increment is more like 1 to 2 dB.

This effect has been observed in the field by other acousticians, where the cumulative noise increment of two equi-distant Wind Machines, has been significantly less than that predicted by the uniform noise source formula.

So the conclusion that can be drawn from this is, that the cumulative noise increment for two near equal noise Wind Machines is between 1 and 3 dB, depending on the phasing of the machines. As a worst-case scenario we will use the uniform noise formula, uncorrected and so the predicted cumulative noise will be the maximum expected value.

The attached spreadsheet shows graphically, on the first sheet, the cumulative noise increment for two, uniform noise sources of varying noise level difference. This is the standard result published by acoustic companys like Bruel & Kjaer.

The second sheet shows graphically the noise versus distance for a single FrostBoss 4-Blade Wind Machine operating alone, on flat terrain, under radiation frost conditions.

The lower table calculates the cumulative noise for up to six FrostBoss Wind Machines. The only input data required is the distance from the noise receiver, to each Wind Machine. These are the yellow, high-lighted cells in column B. If a different Wind Machine to a 4-Blade FrostBoss is being used, then the specific noise level will need to be input for that machine in column C, in place of the calculated value.

The cumulative noise level can then be read directly from the corresponding cell in column E

Finally, it should be noted that this calculation sequence is based on the normal attenuation of sound from a Wind Machine over flat land. Geographic features, other than flat land may amplify or attenuate the noise level from individual machines.

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