DADiSP

WORKSHEET

Noise & Infrasound Analysis

DADiSP　Worksheet
Analysis of noise and infrasound
manual
Sep. 2024

Ver. 1.0

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CAE Solutions

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It is prohibited to copy the provided program other than the method described in "Installation" described in Chapter 1 of this manual.

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foreword

Analysis of noise and infrasound

（C） Yasumasa Uyama

CAE Solutions Co., Ltd. is pleased to announce that we are pleased to provide Noise & Infrasound Analysis to everyone.

There is a growing interest in the prevention of global warming and the SDGs (Sustainable Development Goals), and the development of wind power generation is progressing. Unfortunately, when it comes to analyzing wind turbine sounds, the data recording method and analysis method are not able to cope with the increase in the size of wind turbines.

The Ministry of the Environment (MOE) has stated that "the fundamental frequency f (Hz) of wind turbines is given at f = RZ/60 (Hz) when the number of blades is R (rpm) and the number of blades is Z (sheets), and this fundamental frequency and its higher frequencies are predominant. (For large wind turbines, it is about f=0.5 Hz).

The basics, propagation, influence, and evaluation of low-frequency sound (Hiroaki Ochiai)
It says that "when measuring low-frequency sound, the G-weighted sound pressure level and the 1/3 octave band sound pressure level are measured."

In 1/3 octave analysis, the center frequency is used, so 0.692Hz~0.869Hz is all displayed as 0.775Hz (0.8Hz), and the exact frequency is unknown, and minute changes in frequency and harmonic structure of frequency cannot be grasped.

In the manual on how to measure low-frequency sound,
"3) How to distinguish between wind noise and low-frequency noise

It is not easy to distinguish the difference between the sound pressure level caused by the wind and the target sound pressure level, but the following points should be noted.
In many cases, the low-frequency sound of interest should exhibit a steady, periodic or characteristic change in sound pressure level.
・The sound pressure level caused by the wind changes irregularly. There is.

I created the necessary function to determine this difference, and used specific data to distinguish between wind noise and wind turbine sound.

Required Module: DADiSP/WAV Audio Module

A waveform recording program NX-42WR was added to the NL-62 precision sound level meter of Lion, and the sampling rate was 48 kHz, and the Wav file was recorded with flat characteristics.

The comparison targets include noise data in JFE's plant and road noise data in front of Rion.

For vibration, we used a WAV file recorded with the addition of the waveform recording program VX-55WR to the vibration level meter VM-55 from Lion.

September 2024

CAE Solutions Co., Ltd.

Yasumasa Uyama

Chapter 1　Noise & Infrasound Analysis　Fundamentals

1.1 What is Noise & Infrasound Analysis?

DADiSP has features that allow you to customize it by the user. You can use SPL (Series Processing Language), which is similar to the C language, to add the necessary functions to DADiSP.

Noise & Infrasound Analysis uses SPL to provide the necessary functions for noise and vibration analysis. The function can be used to analyze the data by selecting the required function in the menu system.

The files provided are text files, so you can modify them yourself if you want.

To use Noise & Infrasound Analysis, you need the WAV module.

1.2 Installation

From a single DVD, it can only be installed on one independent computer. If you want to install on more than one computer, buy as many DVDs as you want. In addition, if you plan to use the service with multiple users over a network, purchase a number of DVDs equal to the number of terminal computers that will be connected at the same time.

the folders and files on the dvd are as follows

	--Manual(folder)		
	--jdsp67	--spl--NoiseJ(folder)	
NoiseAnJ10		--dadisp.spl(file)	
		--dadisp.mac(file)	
	--ドキュメント	--DADISP	--Example60(folder)
			--spl--NoiseJ(folder)
			--NoiseVibration.spl(file)
			--dadisp.spl(file)
			--dadisp.mac(file)
			--NL-42_sample_data(folder)
			--NL-62data(folder)
			--VM55data(folder)

Copy the data from the DVD to the corresponding folder. A toolbar is created automatically when DADiSP starts.

If you are already using Dadisp.mac or Dadisp.spl, please do not copy it as follows.

Open DADiSP.spl in Notepad

```
toolbar(1,-1,4,green,"Mva",'MENUFILE("spl¥mvaJ¥mvmenu.men")',"Multivariate analysis ");
toolbar(1,-1,4,green,"Wlt",'MENUFILE("spl¥WltJ¥waveletj.men")',"Wavelet parsing ");
toolbar(1,-1,4,green,"CRF",'MENUFILE("spl¥crfj¥crfj.men")',"Response Functions ");
toolbar(1,-1,4,green,"Noise",'MENUFILE("spl¥noisej¥noisej.men")',"Noise and vibration analysis ");
```

in the function splmain() in DADiSP.spl.

*If you cannot open the sample lab book Example60, please copy it to ¥C:¥Programfiles¥jdsp67¥Example60 . From the DADiSP menu, select "Open" → "Lab Book" → "Example6" and select an example.

In DADISP6.7, the DADISP folder is formed in My Documents, and when you start it normally, it becomes the current folder.

Note 1: You can start working in My Documents with a left-click and save data.
When starting from the current folder Jdsp67, you cannot save data unless you right-click and start as an administrator.
Note 2: If you are using an older version of the worksheet, you may get an error when reading the SPL file. The cause seems to be a change in the way macro definitions are handled. Then

Tools> SPL(S)> Reset SPL
and
Tools> Macro(M)> Reset Macros.

for each worksheet you want to use. In addition, please perform one calculation and finish saving. Your SPL file should be successfully loaded.

1.3 How to use

Once Noise & Infrasound Analysis is installed, noise and vibration analysis is possible.

The steps are as follows:

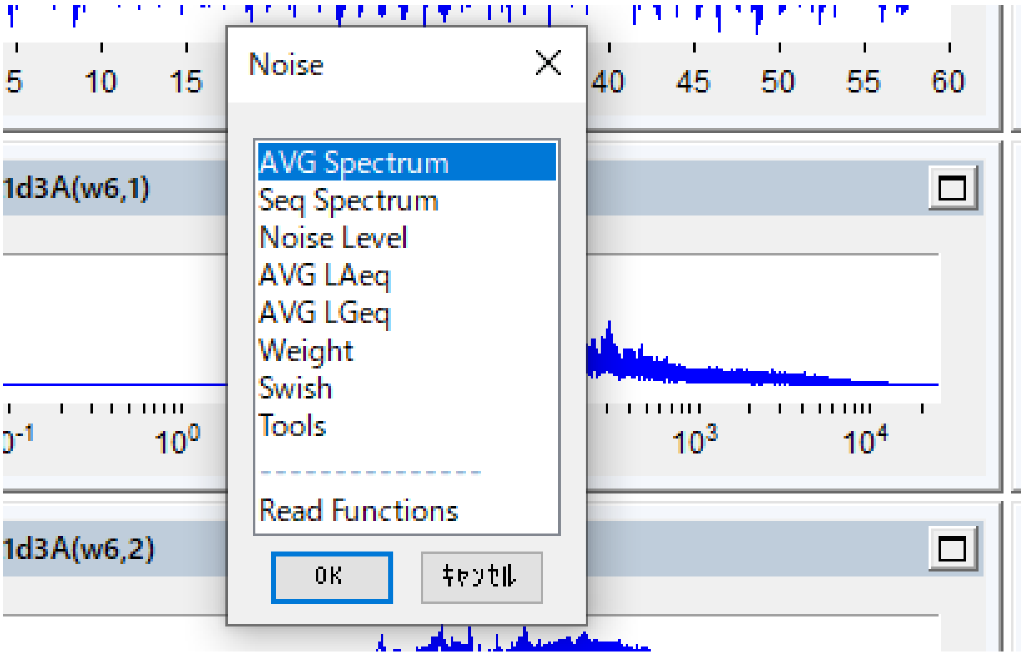
Select File – New – Lab Book and create a new lab book, noisevibbook, in the folder ¥jdsp67 or in the DADISP folder in My Documents.

At this time, a new worksheet is created.

2. **Noise** – **Read Functions** OK to load the functions required for analysis.

It is sufficient to load the function only once, after starting DADiSP.

Click on "Noise" and a menu will appear.



Select ″**Read Functions**″ at the bottom and click ″OK″.

The functions required for analysis are read from the SPL file.

3. Place the data in the worksheet window (let's call it W1).

(There is sample data, so you can call it immediately.))

4. Go to another window and act the function on the window that contains the data.

To select a function, click on the toolbar Noise, select an analysis method, select a function,

In the function panel, specify arguments such as data windows.

- Cumulative effects from long distances

Currently, offshore wind-turbines are being constructed around 2~4km from the shore. Due to the large number of wind-turbines, it is necessary to consider the cumulative effect.

In addition, birds and boats can be considered as things that make noise between wind-turbines and houses, but there are also many things that make noise near houses.

There are various sources of noise between the wind-turbine and the measurement point. A mixture of these sounds is recorded.

It is difficult to extract the components from the wind-turbine, but if the extremely low frequency sound part of the wind-turbine can be measured, it is possible to estimate the part of the wind-turbine noise that is affected by the wind turbine sound in the overall noise.

In addition, in order to assess the cumulative effects of a large number of wind-turbines, it is necessary to take a closer look at the nature of the wind-turbine sound.

The basics, propagation, influence, and evaluation of low-frequency sound (Hiroaki Ochiai)
It says that "when measuring low-frequency sound, the G-weighted sound pressure level and the 1/3 octave band sound pressure level are measured."

In the display of 1/3 octave analysis, the center frequency is used, so 0.692Hz ~ 0.869Hz is all displayed as 0.775Hz (0.8Hz), and the exact frequency is unknown, and the minute change in frequency and the harmonic structure of the frequency disappear, and it is not possible to judge the arrival of the wind-turbine sound and its influence.

The Government of Canada and infrasound

On the Canadian government's website, the introduction to noise says:

The X-axis of the graph represents frequencies from 0.1 hertz (Hz) to 100 Hz, while the Y-axis represents the intensity of the measured sound in decibels (dB). This figure shows an example of measurements taken on a clear summer night at a distance of 2.5 km from four wind turbines. The peaks of 0.8, 1.6, 2.4, 3.2, 4.0, 4.8, 5.6, 6.4, 7.2, and 8.0 Hz in the figure confirm that the measured sound is from a wind turbine, as these specific wind turbines are known to produce sound of these specific frequencies. There is an explanation.

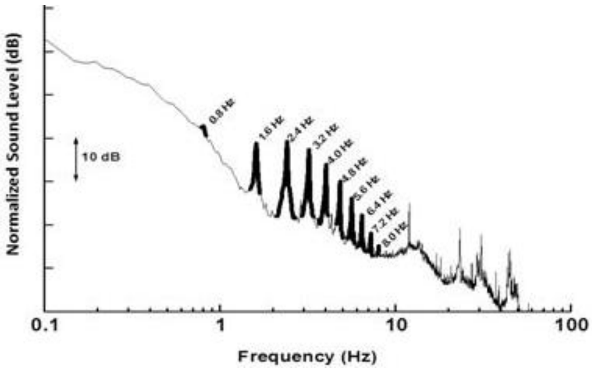


Fig. 1 Noise from Wind turbine

The sound of wind-turbines can be heard at a distance of more than 2.5 km. In order to distinguish whether the measurement result at a distance is wind-turbine noise or environmental noise, it is necessary to grasp the frequency characteristics by accurate frequency. Don't think of it as saying it's 2km from the shore and it's not a problem because it's 1km farther away. In addition, it is necessary to discuss the size of the wind-turbine group and the directionality of the wind-turbine sound.

The infrasound part is a clue to judge the sound of a wind-turbine.

In the manual on how to measure low-frequency sound,

"3) How to distinguish between wind noise and low-frequency noise

In **many cases, the low-frequency sound of interest should exhibit a steady, periodic or characteristic change in sound pressure level.**

・The sound pressure level caused by the wind changes irregularly.

There is.

・Measurement results at Ishikari Bay

Furthermore, by 1/3 octave analysis, the sound of the road in front of Lyon, the sound inside JFE's steel mill, the sound of wind-turbines in Tateyama City, Chiba Prefecture (during strong winds), the sound at the shrine measured by applying wind to a microphone, and the sound pressure level at the flat characteristics calculated from the sound of the wind-turbines at several locations near Ishikari Bay are as follows.

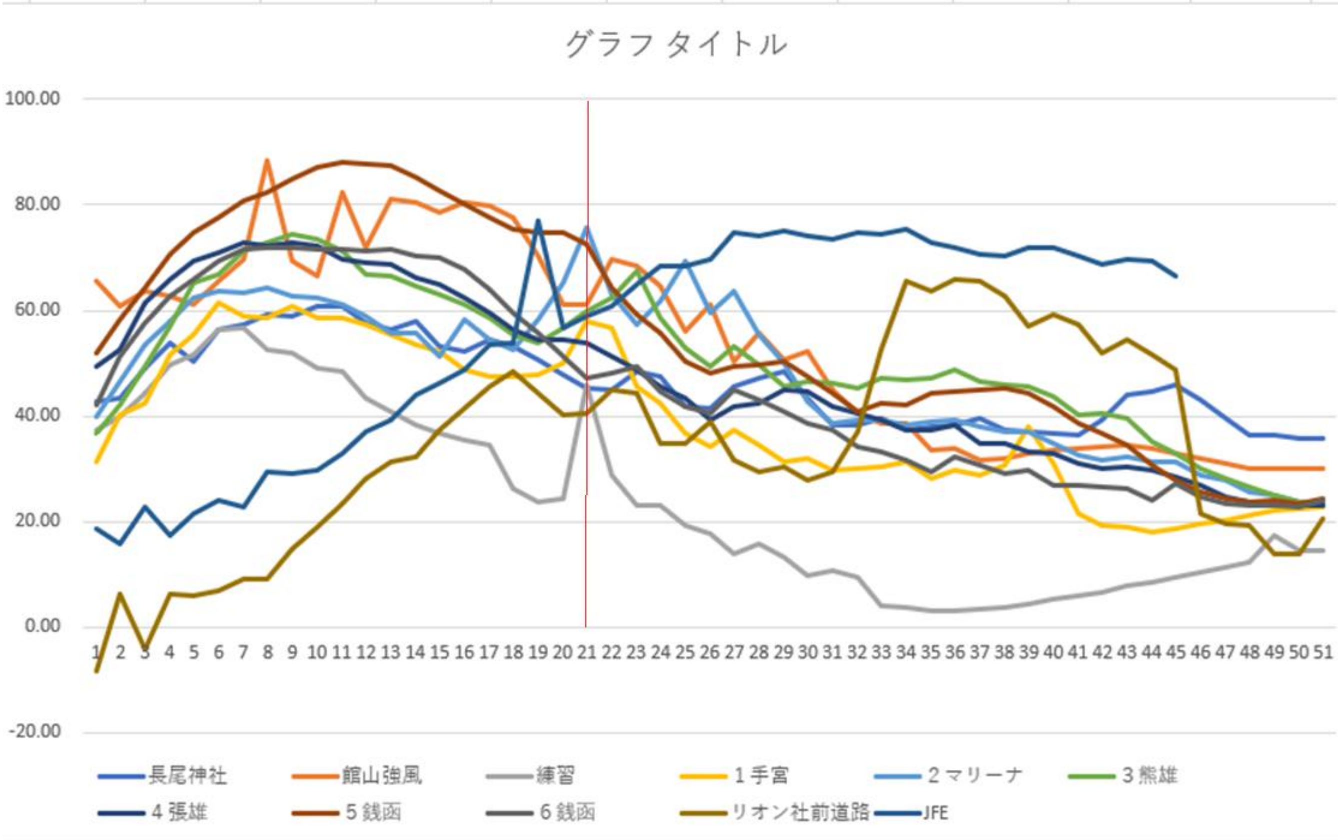
The relationship between the number and the center frequency (0.19Hz~20000Hz) is shown in the following table.

番号	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
中心周波数	0.19	0.25	0.32	0.40	0.50	0.63	0.80	1.00	1.25	1.60	2.00	2.50	3.15	4.00	5.00	6.30	8.00

番号	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
中心周波数	10.00	12.50	16.00	20.00	25.00	31.50	40.00	50.00	63.00	80.00	100.00	125.00	160.00	200.00	250.00	315.00	400.00

番号	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
中心周波数	500.00	630.00	800.00	1000.00	1250.00	1600.00	2000.00	2500.00	3150.00	4000.00	5000.00	6300.00	8000.00	10000.00	12500.00	16000.00	20000.00

20Hz is at number 21. (This is a graph of the flatness characteristic sound pressure level in 1/3 octave analysis.))



In the middle part of the graph (No. 8~ No. 33, 1Hz~315Hz), the sound pressure level of wind-turbine noise decreases as the frequency increases, but the sound pressure level increases as the frequency of traffic noise increases.

The difference is large from No. 8 (1 Hz) to No. 15 (5 Hz). Those who do not want to admit that this is an infrasound from a wind-turbine call this part "wind noise", but if you think about the mechanism by which the wind turbine sound is generated and check the detailed frequency, you can discrete Features of wind-turbine from infrasoundI can see that it is.

Let's consider the figures for Zenibako, which is 10 km from the center of the wind-turbines in Ishikari Bay and 5 km from the nearest wind-turbine.

The noise level (A-weighted sound pressure level) in Zenibako is 40.500459 dB.

Below 20 Hz, the sound pressure of the wind-turbine sound is high, but above 20 Hz, the sound pressure of the sound at the shrine and the sound of the JFE factory is high.

If we consider only the components of 20 Hz or higher as noise, the A-weighted sound pressure level (A) is higher for general noise.

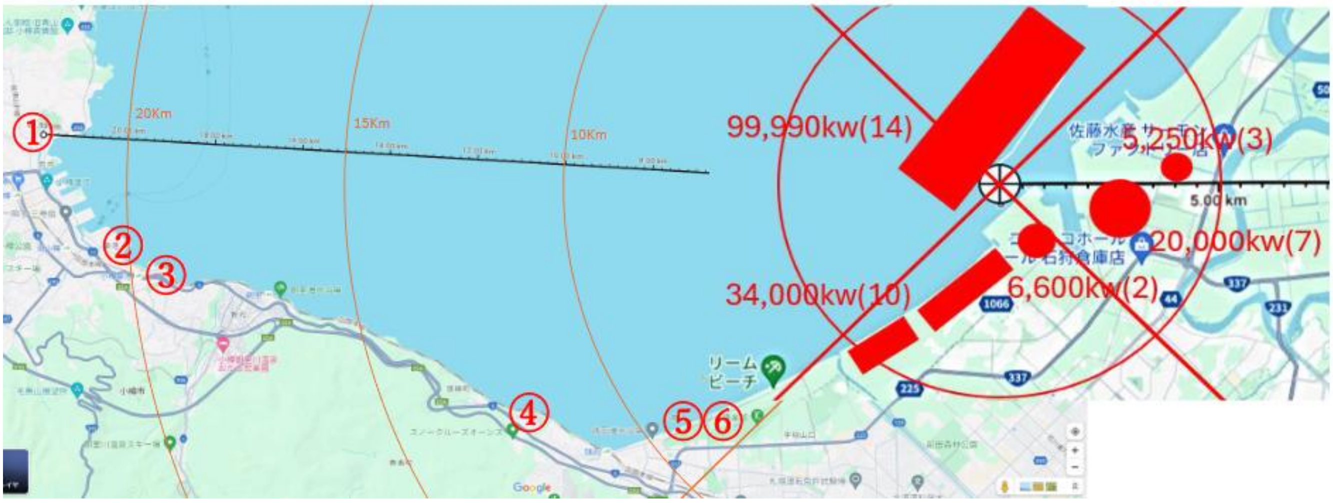
If you calculate the G-weighted sound pressure level (G) (0.25~315Hz), the wind-turbine sound will be louder (depending on the distance).

As a result, G-A is a small number for general noise because G is small and A is large.

In the wind-turbine sound, G is large and A is small, so G-A is a large value.

In Ishikari Bay, there are 14 wind-turbines operating at sea. (In addition, 22 on land, for a total of 36 units) Standing on the sea, a wind turbine. There are 14 of them! This is the second large-scale offshore wind farm in Japan.

This is the measurement result of (1) ~ (6) on the map below. (Mr. Suzuki's"I measured low-frequency sound" from Otaru to Zenibako 2024/3/21)



	場所	開始時刻	測定時間	備考
①	手宮公園	16:17	10分	車通行1～2台、カラス
②	マリーナ	16:50	6分26秒	小型船のエンジンの音、監視船のアナウンス、海猫の鳴声
③	熊碓	17:09	10分	波の音、海猫の鳴声、交通量の多い道路近い
④	張碓	17:44	10分	車の通行３～4台
⑤	銭函	18:14	10分	強風、マイクに直接風が当たらないように車の向きを調整
⑥	銭函	18:25	10分	⑤と同じ場所でドアを閉めて測定

If you leave out the marina and Kumusu, you can see that the G-A is about 20~30 due to the influence of the wind-turbine sound.

At the shrine, G-A = 8.43, which can be judged to be unaffected by the sound of wind-turbines. It is -0.46 at JFE's steel mill and -15.20 on the road in front of Rion. In Kumusu, it is 17.27 due to heavy traffic.

In the case of G-A>15, the influence of wind-turbine noise is significant.

In the case of G-A<10, the effect of wind-turbine noise is small

It can be determined.

	G	A	G—A
手宮1、A=43.69, G=68.92	68.92	43.69	25.23
マリーナ2, A=48.93, G=85.08	85.08	48.93	36.15
熊碓3, A=55.07, G=72.34	72.34	55.07	17.27
張碓4, A=43.31, G=67.85	67.85	43.31	24.54
銭函5, A=52.62, G=87.06	87.06	52.62	34.44
銭函6, A=40.5, G=67.95	67.95	40.5	27.45
館山弱風、A=49.09、G=79.06	79.06	49.09	29.97
館山強風、A=47.74、G=82.92	82.92	47.74	35.18
神社、A=53.02、G=61.45	61.45	53.02	8.43
JFE製鉄所	81.42	81.88	−0.46
道路(リオン社前)	55.92	71.12	−15.20

・Noise measurements and the error of the predicted value

In preparatory documents, etc., wind-turbines are treated as point sound sources to predict the cumulative effects of wind-turbine sounds. However, the fact that the wind-turbine sound is directional indicates that the wind-turbine is not a point source.

Prediction calculations of the sound of 36 wind-turbines in Ishikari Bay (assuming a point sound source)

$$L_n = L_W - 20 * logR - 8 - \Delta L_{AIR}$$

If you use the

風車36基	2000	3000	5000	7000	10000	15000	20000	25000
A	43.35	41.48	39.12	37.68	36.48	35.7	35.47	35.4
G	70	66.49	62.09	59.23	56.25	53	50.86	49.34

However, it is much smaller than the actual measured value.

In the case of a line sound source (Japan Environmental Amenities Co., Ltd.) equation (assuming a line sound source),

$$L_n = L_W - 10 * logR - 8 - \Delta L_{AIR}$$

is too large.

Considering the directivity of the wind-turbine sound and the size of the vibration surface,

Intermediate formula between point and line sources

$$L_n = L_W - 15 * logR - 8 - \Delta L_{AIR}$$

If you use a value that is close to the actual measured value,

風車36基	2000	3000	5000	7000	10000	15000	20000	25000
A	53.61	50.6	46.59	43.84	40.99	38.25	36.9	36.24
G	86.5	83.86	80.53	78.34	76.01	73.38	71.5	70.05

Become.

The cumulative impact is significant, and in the housing complex near Ishikari Bay, at the Teineyaguti (10 km from the center of the wind-turbine group and 5 km from the nearest wind-turbine), the sound of a helicopter landing nearby is echoing.

The distance from the wind-turbine is about the same as that of Zenibako.

In the case of offshore wind power generation, the UK did not regulate the distance to the shore in 2001, but in 2003 it stipulated that it should be 8~13km. In 2009, it was changed to 22.2 km or more.

Germany and the Netherlands are also trying to maintain a separation distance of 22.2 km or more. In China, the distance from the shore is more than 10 km, but in reality, it is more than 20 km away.

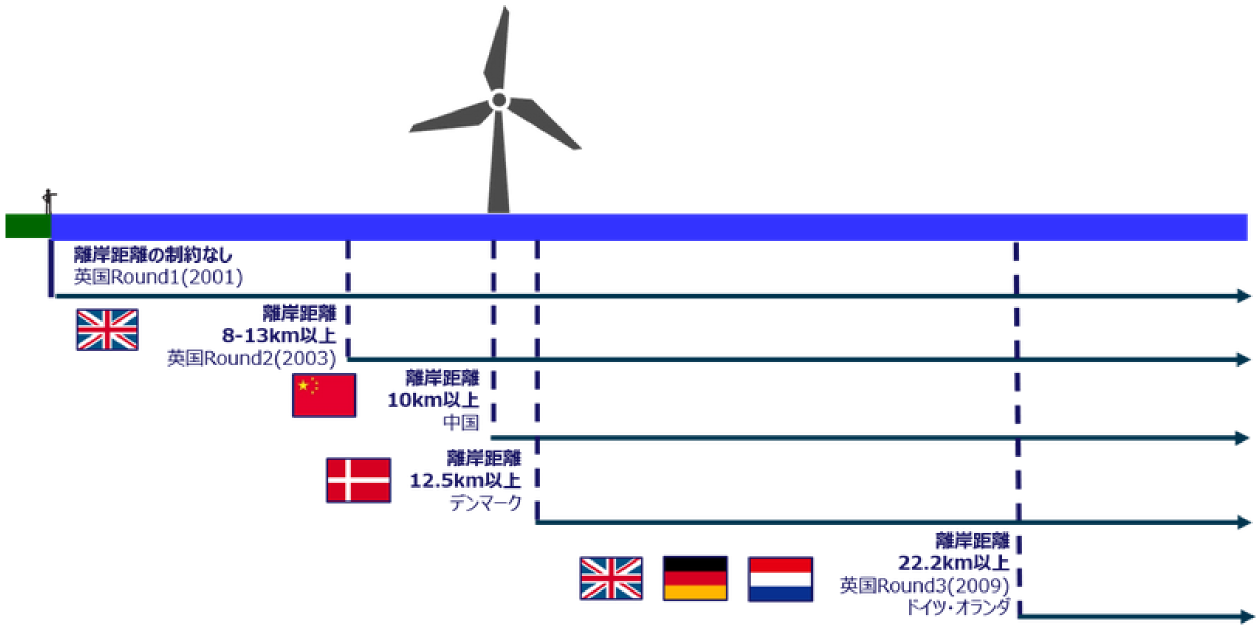


図　諸外国において洋上風力の立地を認める最低離岸距離

参考文献: BMT Cordah Limited, Everington, BSH, 国家能源局, Danish Energy Agency, Gorvernment of the Nethrlands

If you examine the infrasound part in detail, you can estimate the magnitude of the wind-turbine sound component in the measured sound.

If you create a prediction formula that considers the mechanism by which wind-turbine noise occurs, you can estimate the extent of damage.

You need to understand the impact of distant sound sources.

2.1 Measurements and WAV file numbers

Lion Inc.

In the case of Lion equipment,

UC-59L and SA-A1 have a frequency range of DC~20kHz or 0.25Hz~20kHz

NL-62A Measuring range 1Hz~20000Hz

NL-52A Measuring range 10Hz~20000Hz

NL-42A Measuring range 20Hz~8000Hz

NL－27　　Measuring range20Hz～8000Hz

NA－28　　Measuring range　12.5Hz～20000Hz

The lowest frequency can be measured at 0.25 Hz with the SA-A1. At first glance, it seems that it is impossible to measure and analyze sound at 0.5~0.8Hz except for SA-A1, but this is not the case.

The NL-62 and SA-A1 use the same microphone. If a waveform recording program (NX-42WR, SX-A1WR) is built-in, it is possible to record fluctuations in sound pressure applied to the microphone as a WAV file in the form of a signed integer.

When recording sound pressure fluctuations, if the sampling rate is set to 48 kHz and the numerical value is recorded as a 16-bit signed integer, the same value is recorded in the WAV file for both NL-62 and SA-A1.

The reason why there is a difference in the measurement range is that the frequency resolution is increased by increasing the amount of calculation. In order to investigate the frequency content, it is necessary to calculate the FFT.

The sound level meter must display the measurement result on the screen immediately after switching it on. If it takes 60 seconds to measure, the screen will remain stopped for 60 seconds.

If FFT is calculated for 48000 * 1 piece (1 second), the same number of numerical values can be obtained, and if the frequency step width is hHz, h * 48000 * 1 = 48000, so h = 1Hz, and the frequency spectrum is in the range from 0 Hz to 24000 Hz, and the step width is 1 Hz.

The frequency spectrum for 48000 * 60 pieces of data (1 minute) is displayed in the range of 0Hz ~ 24000Hz in increments h = 0.01667Hz.

If the measurement results for 120 seconds are analyzed, the frequency resolution is 0.0083 Hz, so if the data is calculated for 120 seconds, it is possible to distinguish the difference between infrasound and other noise from wind turbines, which have a steady and periodic nature.

In view of the processing time and frequency resolution required, it is impossible to analyze WAV files with NL-62 (+ waveform recording software NX-42WR) alone.

The range that can be represented by signed integers is that when two's complement is used for negative numbers, values in the range of –2^15 ~ 2^15 -1 are used for 16-bit signed integers. One more negative number.

As for the range of sound pressure that can be measured with a sound level meter, the maximum sound pressure that can be measured with a sound level meter (with low-frequency sound measurement function) is described in the NL-62 instruction manual as a maximum of 148 dB.

In the section on display and output full scale, it is written that the full scale of the output voltage can be set up to

70dB ~ 130dB in 10dB increments.

Here, when 130dB is selected, the WAV file name is

NL_001_20220503_111400_130dB_0008_0000_ST0001

From the middle part of the name, you can see that the full scale of the output voltage is set to 130 dB.

The data recorded in the WAV file is designed to handle a slightly larger sound pressure, and (display output full scale value + 13) dB is the full scale value of the WAV file.

If the setting is 130 dB, the full-scale value in the WAV file is 143 [dB], which means that 2×10^(-5)×10^(143/20) = 282. 5075088 Equivalent to [Pa].

RMS 282. For information on how to describe the value of 5075088Pa (143dB) in the WAV file, see
Depends on the file.

A 16-bit signed integer is in the range {+2^(15)-1}~(—2^15), and the sound pressure is -282. For the case of 5075088Pa, a negative integer -2^15 = -32768 is corresponded.

At this time, the integer value 1 is -282. 5075088Pa/ (-(2^(15)))=8.62144497*10^(-3) Pa (rms). The integer value k means k*82144497*10^(-3) Pa (rms)

If the calculations are troublesome, you can use the AS-70 (trial version is free.) and perform the following operations.

Display - The value of Value/Bit (8.621445E-5) can be used as the file information.

In the calculation of the frequency spectrum on a PC, the read signed integer data is subtracted from the average value, and then multiplied by 8.621445E-5 to get the Pascal value.

If there is this frequency spectrum, the characteristics of the wind-turbine sound can be found as shown in Table 1.

2. WAV ファイルのヘッダ情報(Windows 標準)

4 byte	'R' 'I' 'F' 'F'	RIFF ヘッダ	
4 byte	これ以降のファイルサイズ (ファイルサイズ - 8)		
4 byte	'W' 'A' 'V' 'E'	WAVE ヘッダ	
4 byte	'f' 'm' 't' ' ' (←スペース含む)	fmt チャンク	
4 byte	バイト数	fmt チャンクの バイト数	リニア PCM 16(10 00 00 00)
2 byte	フォーマット ID		リニア PCM 1(01 00)
2 byte	チャンネル数		モノラル 1(01 00)
4 byte	サンプリングレート Hz		48kHz 48000(80 BB 00 00)
4 byte	データ速度 (Byte/sec)		48kHz 16bit モノラル 48000×2 = 96000 (00 77 01 00)
2 byte	ブロックサイズ (Byte/sample×チャンネル数)		16bit モノラル 2(02 00)
2 byte	サンプルあたりのビット数 (bit/sample)	WAV フォーマットでは 8bit か 16bit	16bit 16(10 00)
4 byte	'd' 'a' 't' 'a'	data チャンク	
4 byte	バイト数 n	波形データのバイト数	
n byte	波形データ		

7) Wave (raw waveform data output): W

W: Submit → Reply: Data

16-bit binary AD raw value output

Ends with the End Measurement (E) command.

: Data content

Waveforms (sound pressure fluctuations) of 48 kHz sampling (20.8 μs) are continuously discharged.

The value is a 16-bit signed integer.

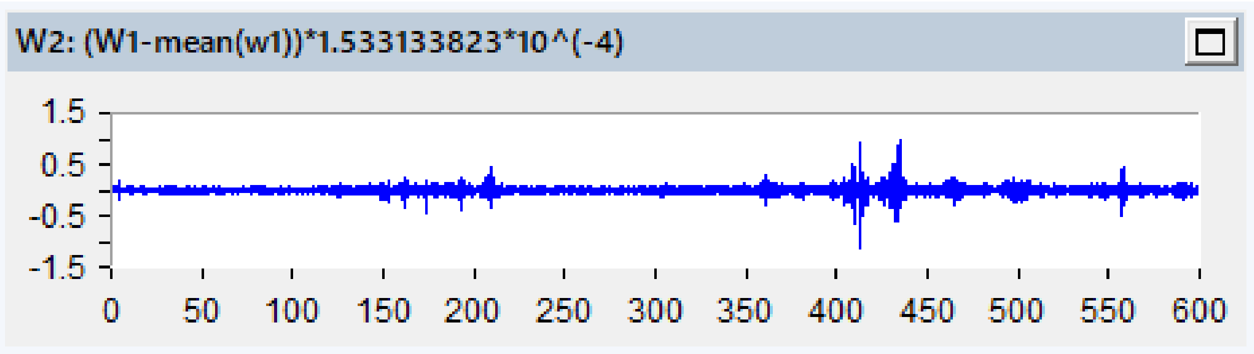
```
0|0000000 00000000 : 0
0|0000000 00000001 : 1
0|0000000 00000010 : 2
0|1111111 11111111 : 32767
1|1111111 11111111 : -1
1|1111111 11111110 : -2
1|0000000 00000000 : -32768
```

The values range from the maximum value of +32767 to the minimum value of -32768.

When the maximum value of the range is 100 dB, the margin in the measurement is 8 dB
Measurement day,Measurement time,Frequency-weight,Level Range,Time setting
24/03/17,02:20:00,Z,100dB,003h00m00s
The annotation on the file says 100 dB.
If you add the margin of 8 dB, you get 100 + 8 = 108 dB.

If the corresponding sound pressure (rms value) is P,
From 108=20log(P/(20*10^(-6)), P=5.023772912 (Pascal) and -P=-5.023772912 Pascal value is -32768=-(2^15)
Respond to:
The integer +1 corresponds to 5.023772912/32768=1.533133823*10^(-4)(Pascal),
The integer value k corresponds to 5.023772912 * (k / 32768) = 1.533133823 * 10^ (-4) * k (Pascal).
(I understood the manual as above.))

To convert a read signed integer to a Pascal value, multiply by 1.533133823*10^(-4).



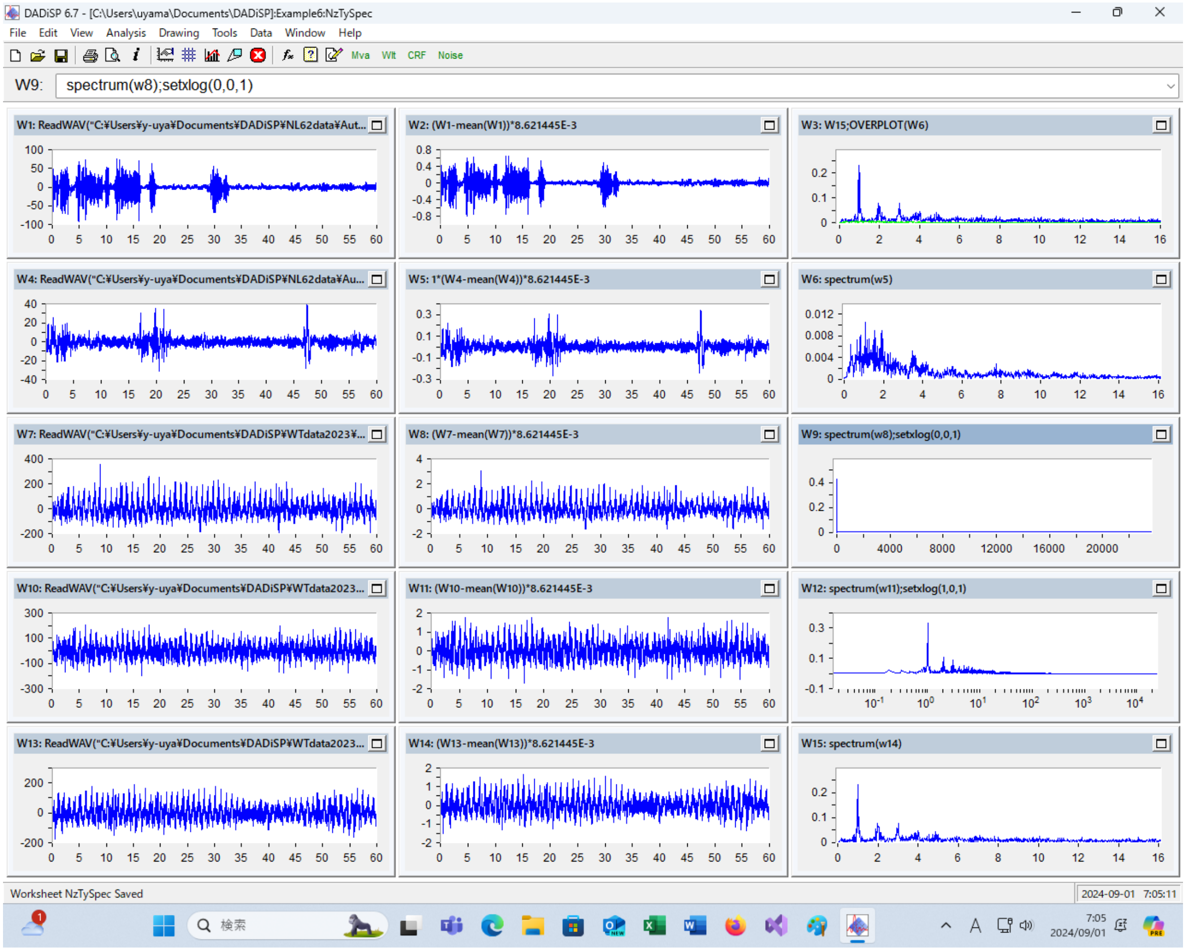
The rest is the same.

2.2 Analysis of measurement data

File → Open → Lab Book → Example6

If you open the worksheet NzTySpec in the lab book Example 6, you will see the following. In addition **Noise** – **Read Functions** OK to load the functions required for analysis.

NzTySpec



W７：

ReadWAV("C:¥Users¥y-uya¥Documents¥DADiSP¥WTdata2023¥Closed3¥Auto_0010¥SOUND¥NL_001_20231216_115100_130dB_0010_0000_ST0002.wav", 0, 1)

The

Tools - Modules - WAV - Read WAV file

WAV file loaded as

W8:

(W7-mean(W7))*8.621445E-3

as a Pascal value.

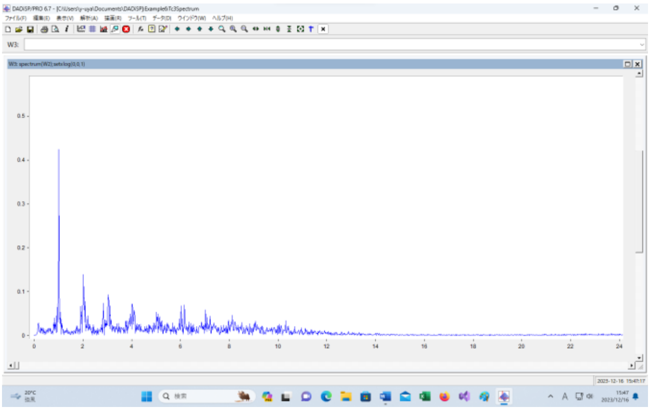
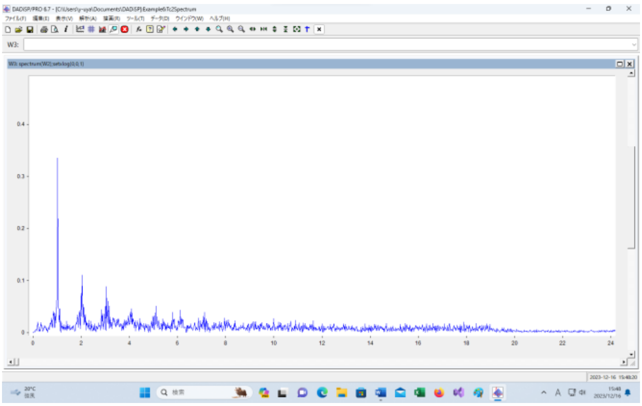
W9:
spectrum(w8)
The frequency spectrum was calculated.

W7, W10, and W13 are the results of the following measurements in the vicinity of the wind turbine. (The sound pressure changes with the change in wind speed.))

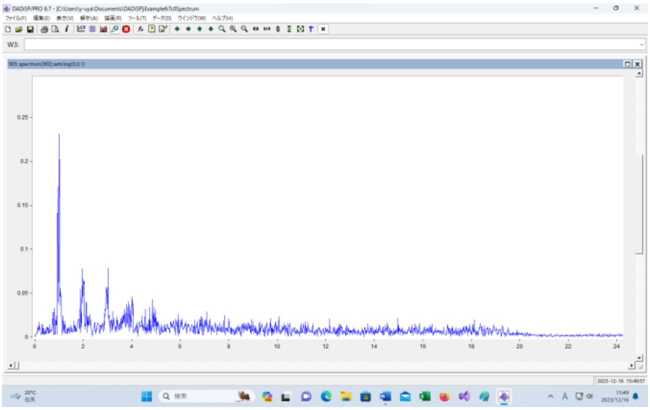
Measurement near the wind-turbine,
Put the sound level meter in a plastic bag, put it in a cardboard box, cover it with vinyl,



W7: Bag and box, door closed, Max. 0.42Pa W10: Bag and box, door opened, Max. 0.33Pa

W13: Take out of the bag, put on the box, Max. 0.23Pa



The W7 and W10 are not wind noise because the wind does not hit the microphone. The infrasound generated by the wind-turbine was measured.

If a wind-turbine is nearby, if you compare the results when the wind does not hit the microphone and the results when the wind hits the microphone, you can observe infrasound with high sound pressure and regular frequencies in both cases.

The parts that have high sound pressure and regular frequencies are very similar whether the wind hits them or not.

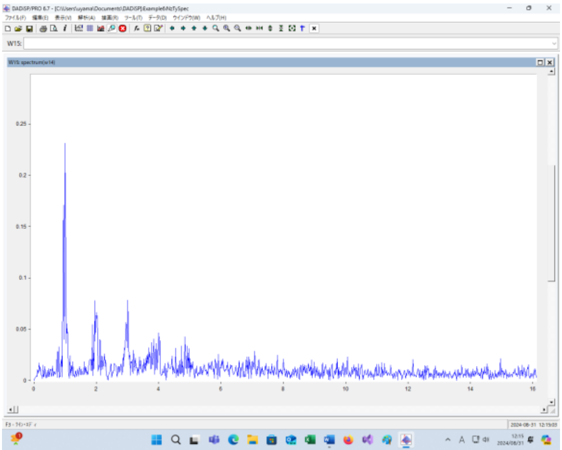
This means that the sound pressure of the noise part is low due to the wind hitting the microphone.

W1 and W4 are sounds measured while blowing wind into a microphone in the precincts of a shrine, 20 km away from the wind-turbine.

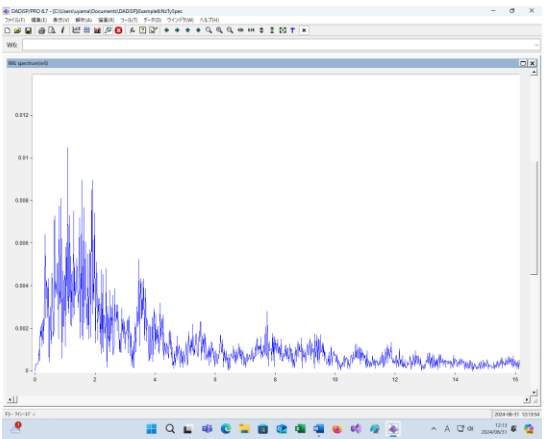
Without a wind-turbine, even if the wind is applied to the microphone, infrasound with high sound pressure and regular frequencies will not be measured.

In a place where there is no wind-turbine, if you measure by blowing the wind through a microphone, infrasound sound with low sound pressure and no frequency regularity will be measured.

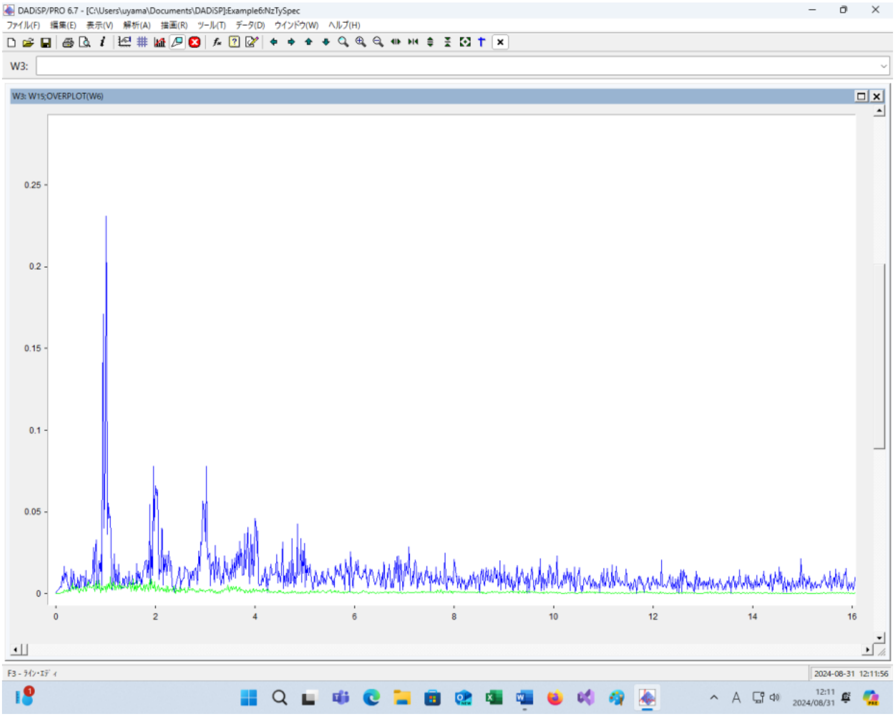
This is the low-frequency part of W15. It is characterized by discrete and regular peak values.



This is the low-frequency part of W6.



W3 is a superimposed version of W15 (blue) and W6 (green).



of manuals on how to measure low-frequency sound,

"3) How to distinguish between wind noise and low-frequency noise

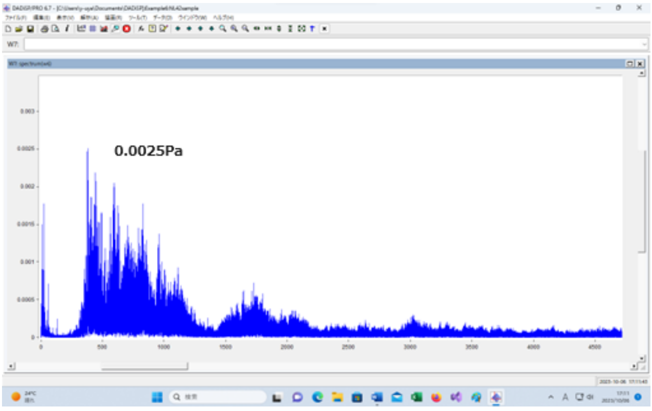
In many cases, the low-frequency sound of interest should exhibit a steady, periodic or characteristic change in sound pressure level.

・The sound pressure level caused by the wind changes irregularly. "

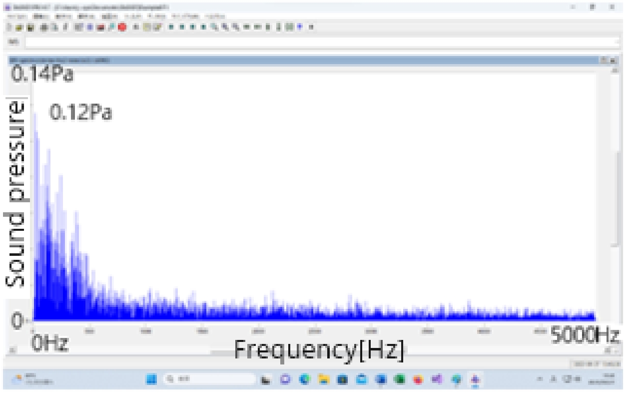
But it turns out to be correct.

2.3 Comparison of noise characteristics

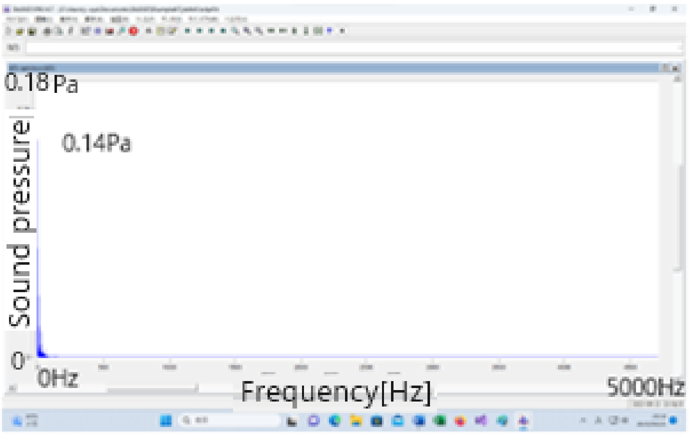
Traffic sound(0~5000Hz).



Workshop sound(0~5000Hz).

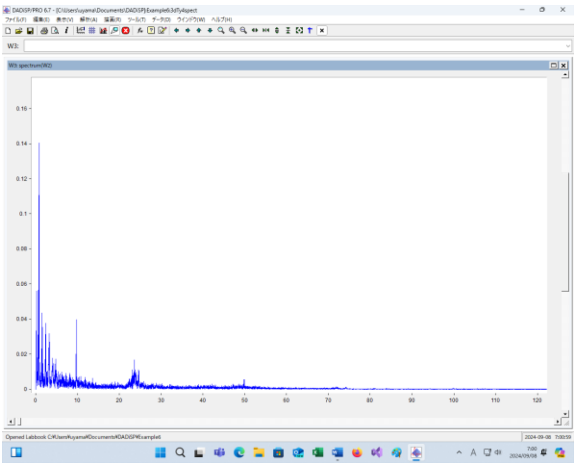


Wind turbine sound (0~5000Hz) (on days when the wind is light).

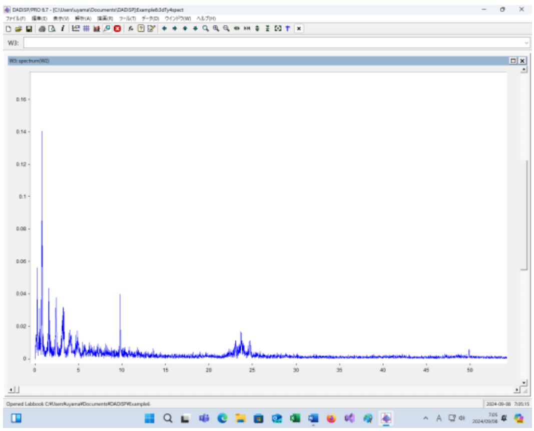


If we take a closer look at the frequency spectrum of windmill sounds, we can see the following.

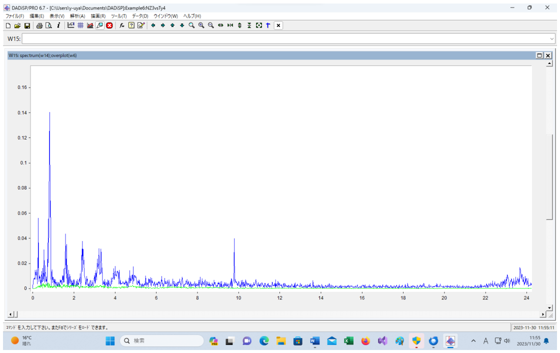
0～120Hz



0～50Hz



0～24Hz



The distribution of energy is as follows.

Table 2: Distribution of energy Distribution of energy at 0~20Hz

エネルギー分布	0～20Hｚ	20Hｚ以上
風車音	93%	7%
工場音	12%	88%
交通音	1%	99%

Energy distribution	0～1Hz	1～20Hz	0～20Hz
Wind turbine	61.3%	38.7%	100.0%
Iron mill	0.04%	99.96%	100.0%

Now, since 93*0.613=57%, 57% of the energy of the entire wind-turbine sound is contained in the part where the frequency is lower than 1 Hz. It can be said that the energy distribution of wind-turbine sound is concentrated at one point.

Factory noise and traffic noise can be said to be wideband sound because the sound energy is distributed over a wide band.

Windmill sound cannot be called a wideband sound because the sound energy is concentrated in a narrow band.

The definition of "infrasound" in ISO7196 is:

3 Definitions

For the purpose of this International Standard. The following definitions apply.

3.1 infrasound: Sound of noise whose frequency spectrum lies mainly in the band from 1 Hz to 20 Hz.

It has become.

"Infrasound" is not defined as "1~20Hz sound waves", but as "sounds whose frequency spectrum mainly falls into the band of 1Hz to 20Hz".

Exactly, the sound of wind-turbine has this nature. The sound of wind-turbine is "infrasound" itself.

The effect of soundproof windows on such sounds can be seen from the following graph.

The sound pressure of the wind-turbine is high in the part below 10 Hz. In particular, components below

4 Hz have an outstanding sound pressure, so soundproofing effects with aluminum sash double-glazed windows cannot be expected.

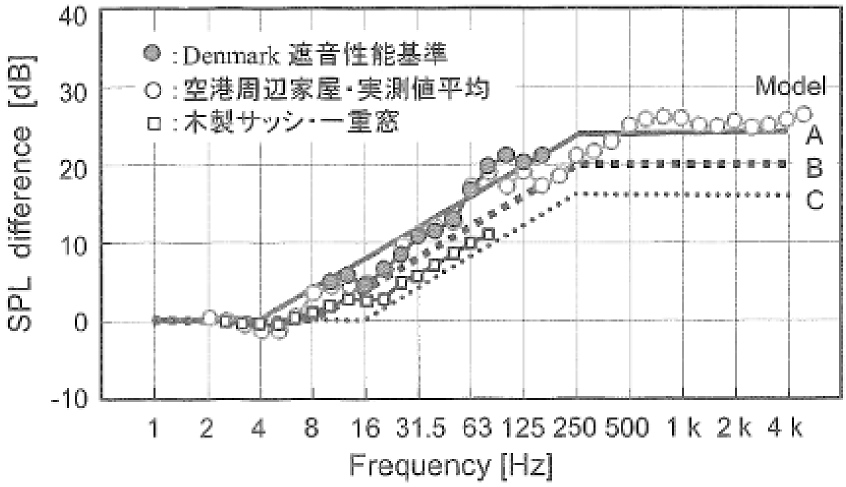


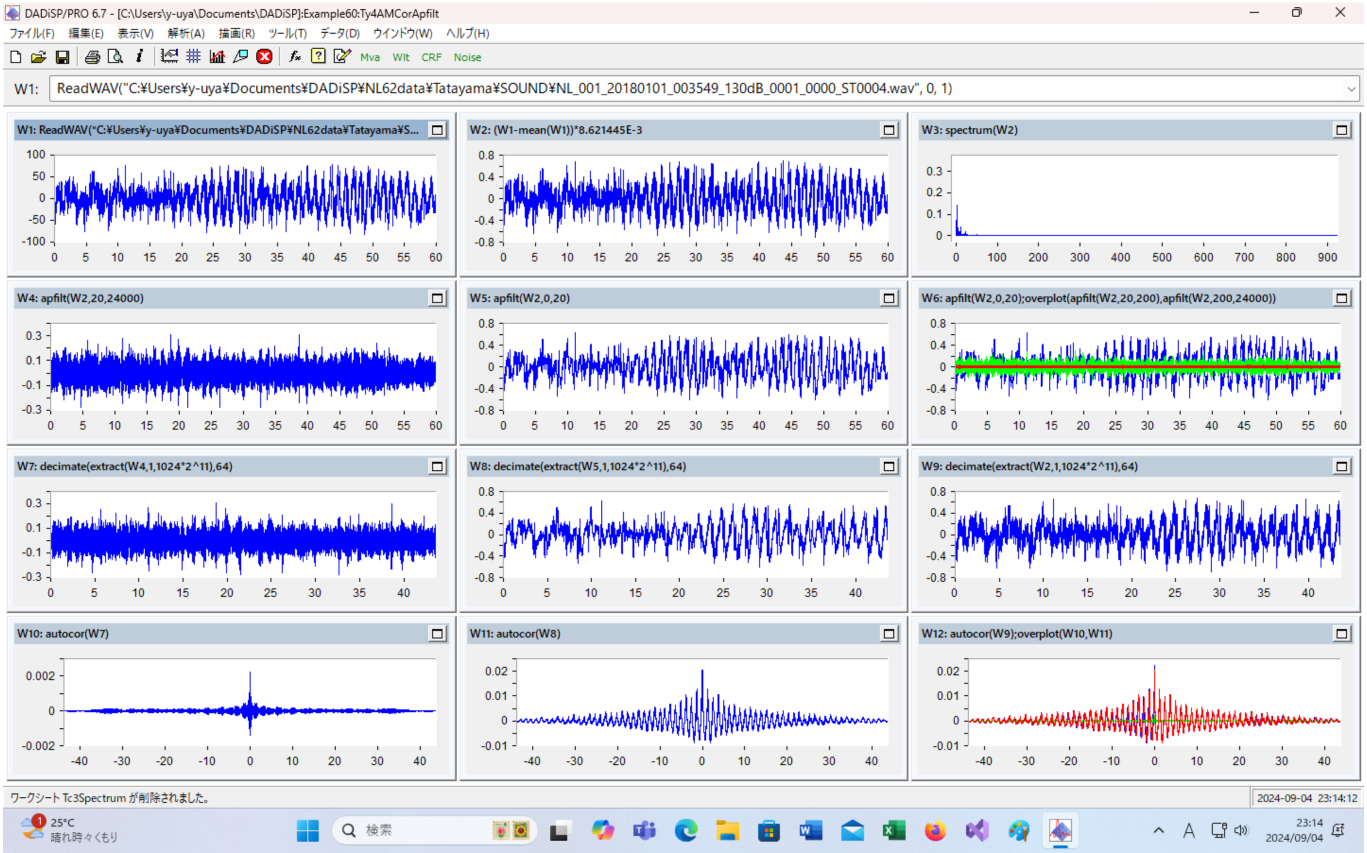
図５　ハウスフィルター・モデルと３種類の参照データの比較

2.4 Components of wind-turbine sound

File → Open → Lab Book → Example6

If you open the worksheet Tc3Spectrum in the lab book Example 6, it will look like this.

Ty4AMCorApfilt



The W1 reads data recorded with the NL−62.

In W2, the value of a signed integer is converted to a Pascal value.

In W3, the frequency spectrum is calculated.

In W4, components in the range of 20~24000Hz are extracted from W2.

In W5, components in the range of 0~20Hz are extracted from W2.

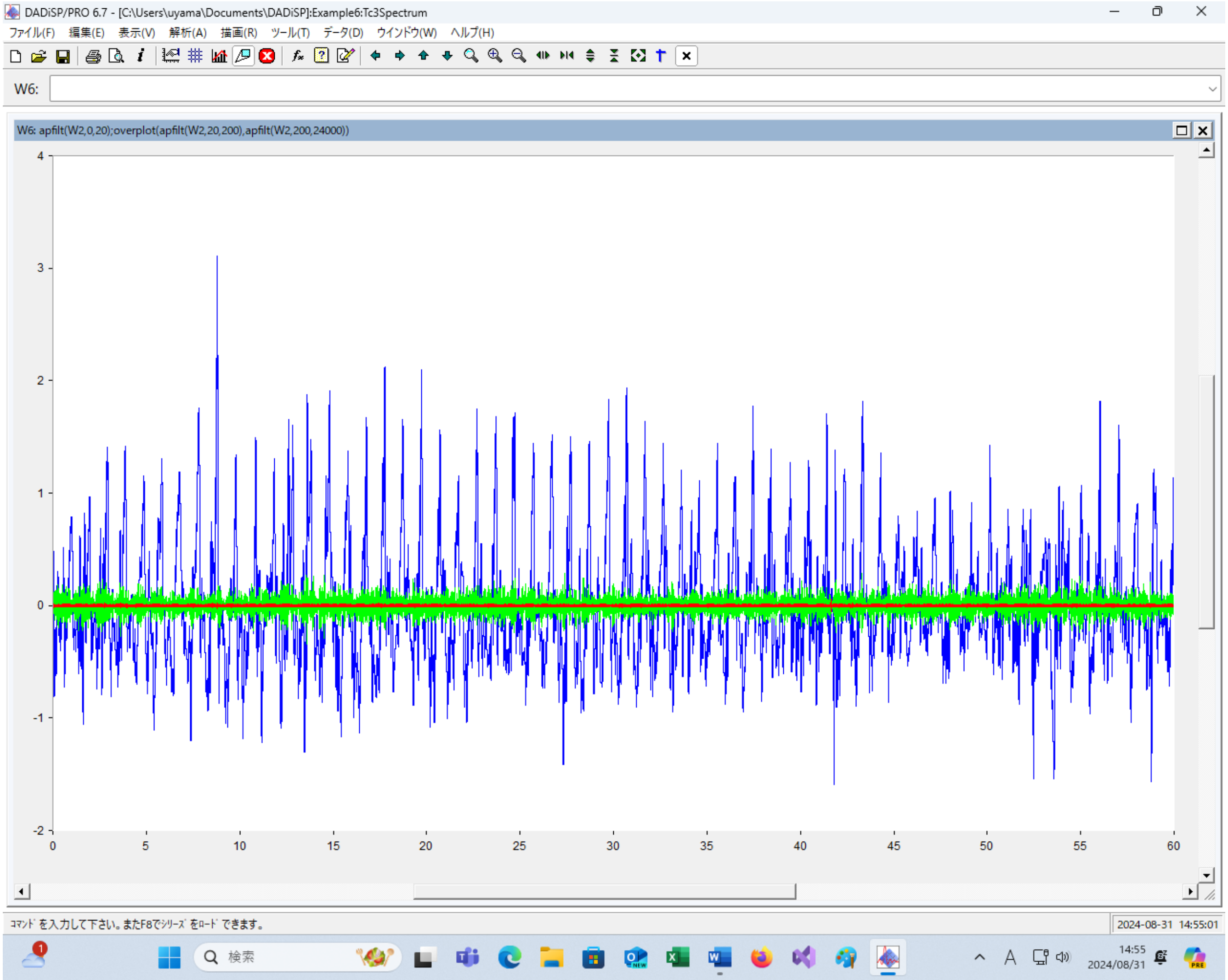
In W6, the graphs of the 0~20Hz component (blue), the 20~200Hz component (green), and the 200~24000Hz component (red) are superimposed.

In W7, W8, and W9, the number of data is reduced by thinning.

W10, W11, and W12 are looking for autocorrelation.

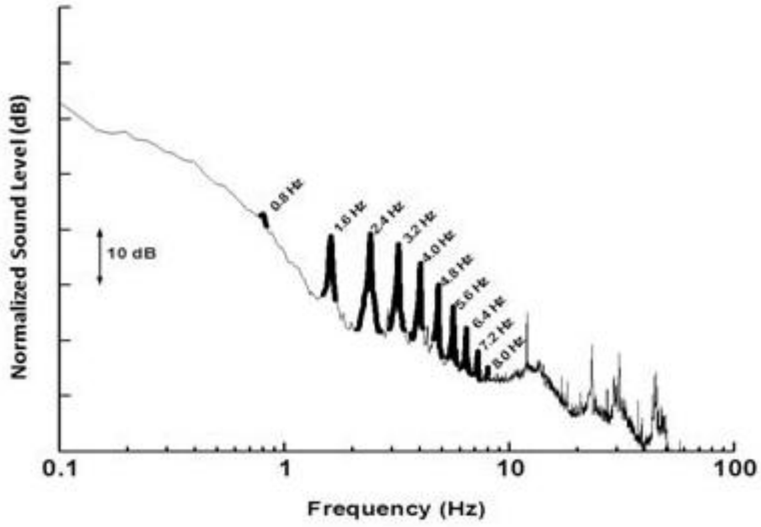
If you compare the wind-turbine sound divided by frequency band (0~2, 20~200, 200~24000Hz), you can see that the sound pressure of the infrasound part is outstanding.

W6: 0~20Hz component (blue), 20~200Hz component (green), 200~24000Hz component (red).



In the Canadian literature A Primer on Noise,

"The rotation frequency of a sound source can be used to identify the sound source that is emitting the sound. For example, the base frequency of a wind turbine with three blades rotating at 16 revolutions per minute (RPM) corresponds to 0.8 Hz (i.e., (3 blades X 16 RPM) divided by 60 seconds). Thus, in this example, the wind turbine sound can be separated from the background noise if the noise level from the wind turbine is high enough to show a frequency peak at a multiple of the fundamental frequency and the fundamental frequency in the sound measured at a certain distance. These multiples are called harmonics, and for a source with a fundamental frequency of 0.8 Hz, they can be 1.6 Hz, 2.4 Hz, 3.2 Hz, 4.0 Hz, 4.8 Hz, etc."



"Frequencies below 20 Hz are classified as infrasound and, as mentioned above, are generally outside the range of human hearing at the noise levels that normally occur. Infrasound is common in the environment and can come from naturally occurring phenomena such as thunderstorms, volcanoes, and earthquakes, or from man-made sources such as rocket launches, explosions, and some mining activities. Infrasound can also occur in large wind turbines and large boilers. Low-frequency noise is used to describe frequencies between 20Hz and about 200Hz. The perception of infrasound or infrasound (below about 30 Hz) is often described as a "sensation" or "pressure" rather than an audible one. This type of noise is easily transmitted from the outside of the building to the interior of the building, so depending on the level, the lightweight structures inside the house can vibrate or rattle, causing annoyance. "

There is,

Next Paper

Wind Turbines and Health

A Critical Review of the Scientific Literature

McCunney, Robert J. MD, MPH; Mundt, Kenneth A. PhD; Colby, W. David MD; Dobie, Robert MD; Kaliski, Kenneth BE, PE; Blais, Mark PsyD

Author Information

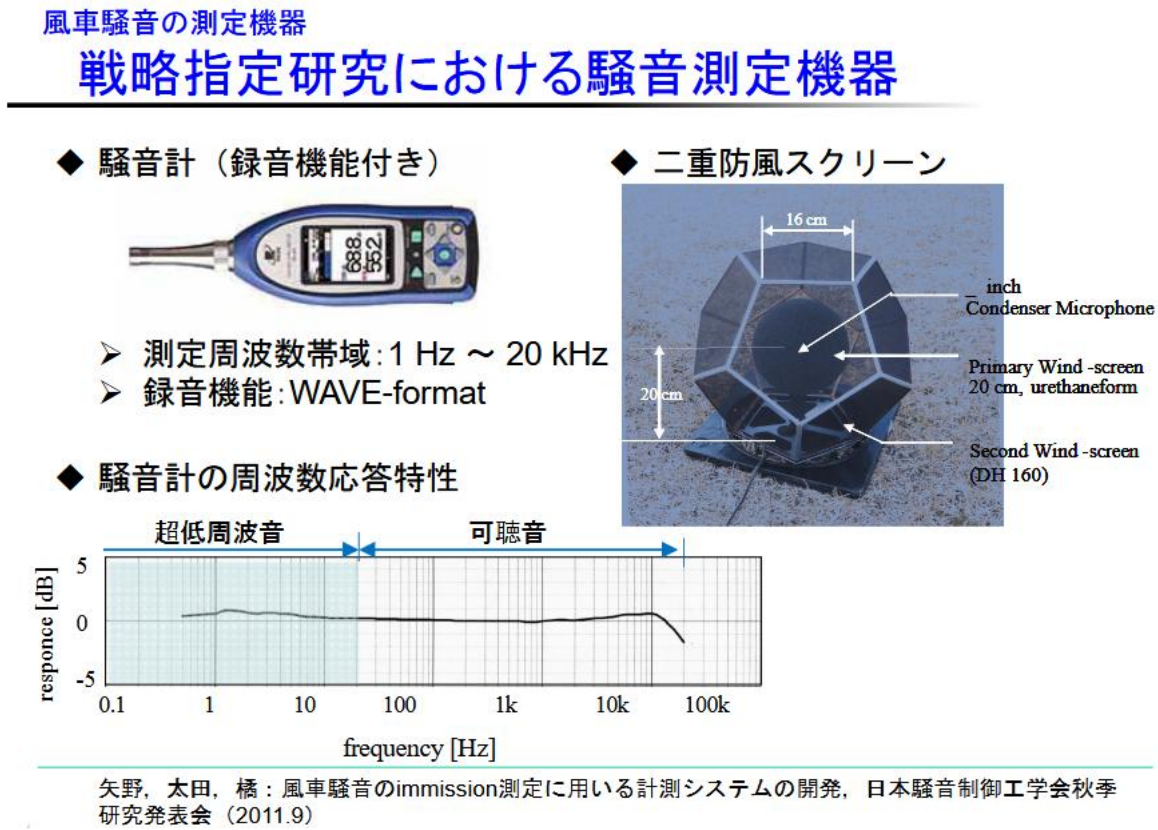
Journal of Occupational and Environmental Medicine 56(11):p e108-e130, November 2014. | DOI: 10.1097/JOM.0000000000000313

The main problem with measuring low-frequency sound and infrasound in environmental conditions is wind-caused pseudosound due to air pressure fluctuation, because air flows over the microphone. With conventional sound-level monitoring, this effect is minimized with a wind screen and/or elimination of data measured during windy periods (less than 5 m/s [11 mph] at a 2-m [6.5 feet] height).[36] In the case of wind turbines, where maximum sound levels may be coincident with ground wind speeds greater than 5 m/s (11 mph), this is not the best solution. With infrasound in particular, wind-caused pseudosound can influence measurements, even at wind speeds down to 1 m/s.[12] In fact, many sound-level meters do not measure infrasonic frequencies.

The main problem in measuring low-frequency and infrasound in environmental conditions is the simulated sound caused by the wind due to fluctuations in air pressure, since the air flows over the microphone. Traditional sound level monitoring minimizes this effect by removing data measured during windy periods (less than 5 m/s [11 mph] at a height of 2 m [6.5 ft]). [36] For wind turbines, this is not the best solution, as the maximum noise level can match surface wind speeds in excess of 5 m/s (11 mph). Especially in infrasound frequencies, pseudo-sounds caused by the wind can affect the measurement even if the wind speed drops to 1 m/s. [12]. In fact, many sound level meters do not measure infrasound frequency frequencies.

As a result, the view of the Ministry of the Environment of Japan has also changed from a tendency to emphasize infrasound to a tendency to ignore infrasound sound.

As for wind noise,
"2.3.5 Wind noise:
Noise caused by wind hitting the microphone. In measurement, it is necessary to reduce wind noise by attaching a windscreen (windproof screen) (see 3.1 (2)).
The rustling of leaves and wind noises caused by the wind are natural sounds, not wind noise. ”
(2) Windscreen (windproof screen)
When measuring noise under wind conditions within the effective wind speed range of wind turbines, wind noise cannot be sufficiently reduced with a commonly used windscreen with a diameter of 10 cm or less. To reduce the effects of wind noise, it is necessary to use a larger, all-weather windscreen.
If the influence of the wind is large, use a windscreen with better performance, such as a double windscreen.
Note: If wind noise cannot be sufficiently excluded even by using double windscreens, etc., it is necessary to take measures such as excluding the area of influence of wind noise by performing sound exclusion processing. “
It says that the measurement result should be completely erased by "exclusion sound processing".



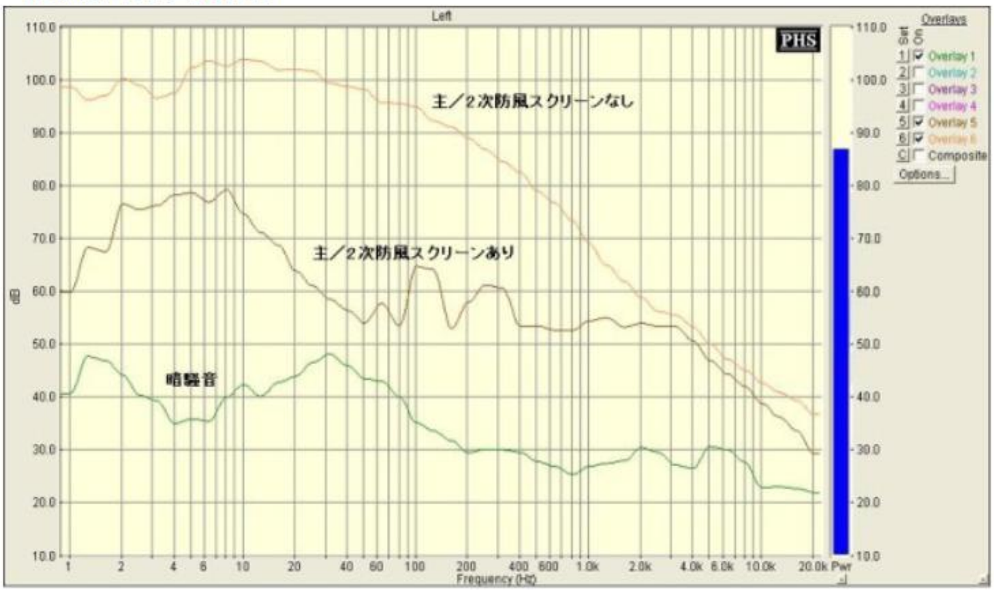
The attenuation effect of the double windproof screen is shown in the following graph.

２次防風スクリーン Φ460×230(H)

主防風スクリーン Φ90半割内蔵

組　　立　：簡易取り付け方式（約10分）

【風切音減少効果】



60デシベルの差とは→	百万倍の差
50デシベルの差とは→	10万倍の差
40デシベルの差とは→	1万倍の差
30デシベルの差とは→	1千倍の差
20デシベルの差とは→	100倍の差
10デシベルの差とは→	10倍の差

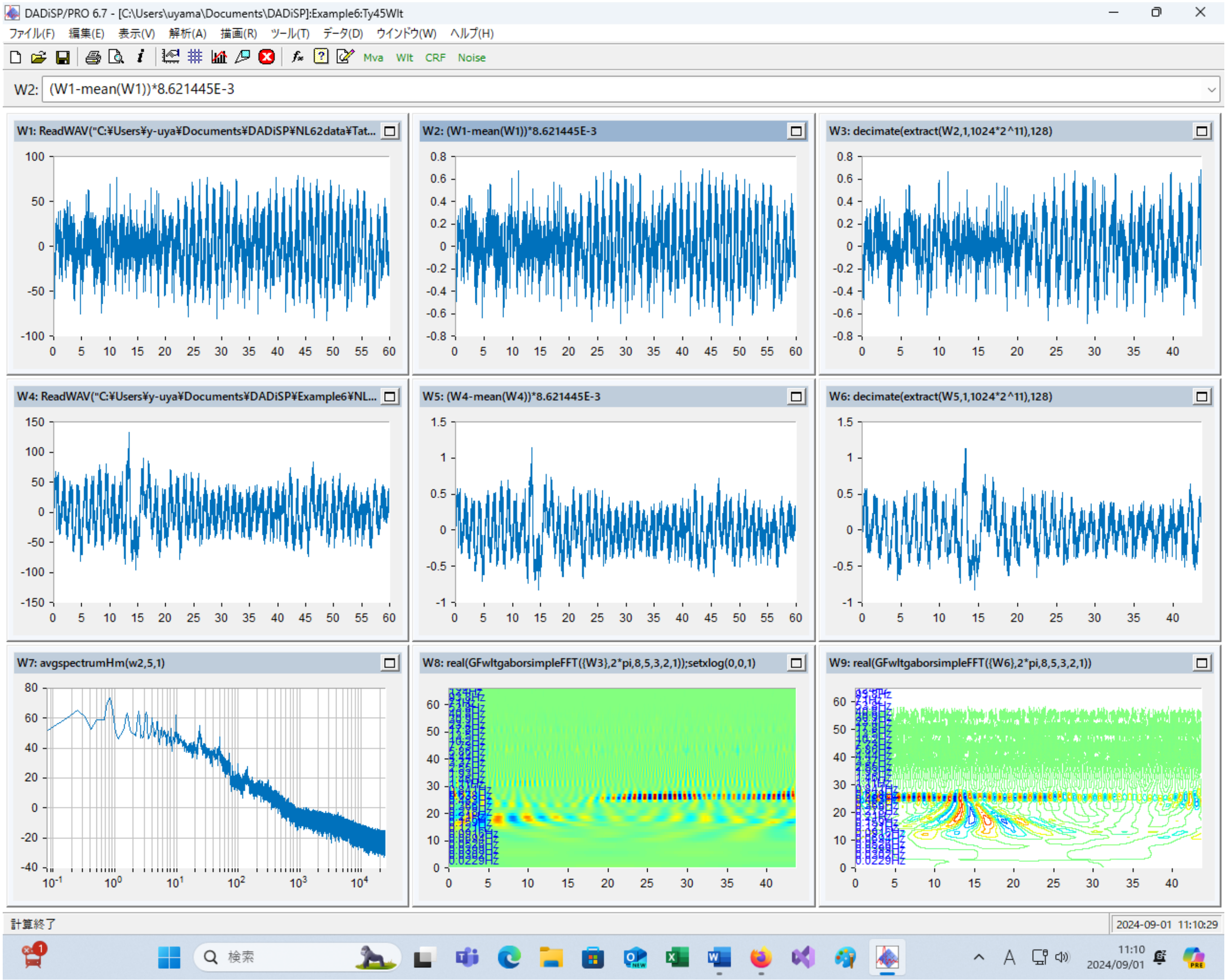
The result of measurement with a double windproof screen is about 20dB ~ 40dB attenuation between 1 ~ 500 Hz, so it is observed as a value of about 1/5000 of the actual sound pressure. In this case, it is natural that the cause of the damage is unknown.

2.5 Wavelet

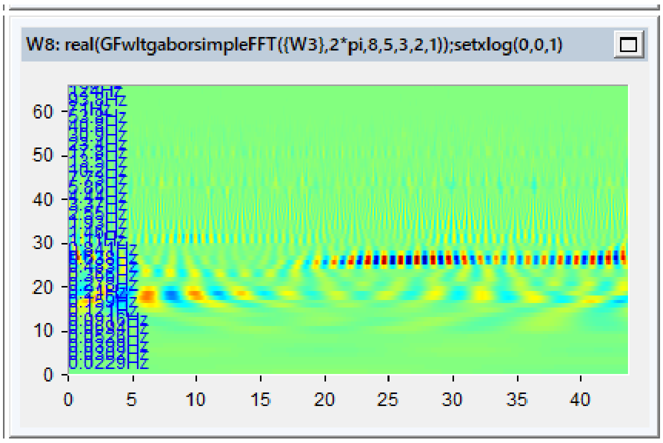
The Ministry of the Environment said that if the number of revolutions of the wind turbine is R and the number of blades is Z in 60 seconds, the wind turbine will emit a sound of RZ/60 Hz. This value is about 0.5 Hz for today's large wind turbines.
As the wind speed increases, the lift force increases and the number of revolutions can increase. Of course, the angle of the blade with respect to the wind direction is changed and the rotation speed is adjusted so that the rotation speed is constant, but when I shot a video, it seems that the adjustment cannot keep up with the change in wind speed because of the drastic change in wind speed.

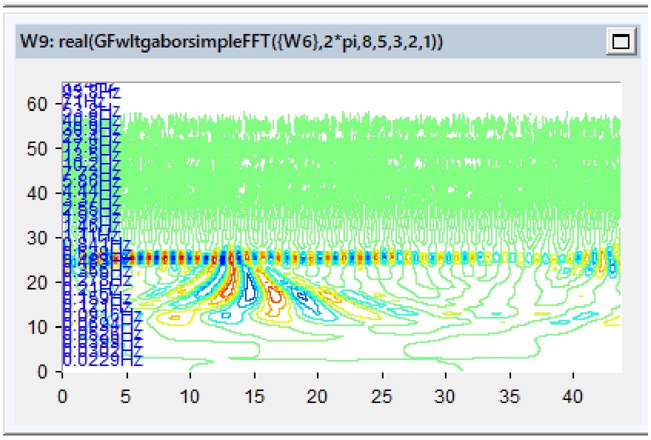
To see the relationship between frequency fluctuations and sound pressure, Wavelet analysis is useful.

Ty45Wlt



The two graphs on the bottom right show the presence of a 0.8 Hz component. Darker colors mean higher sound pressure, while lighter colors have lower sound pressure. If you look closely, you can see that in addition to sound pressure, the frequency also changes.



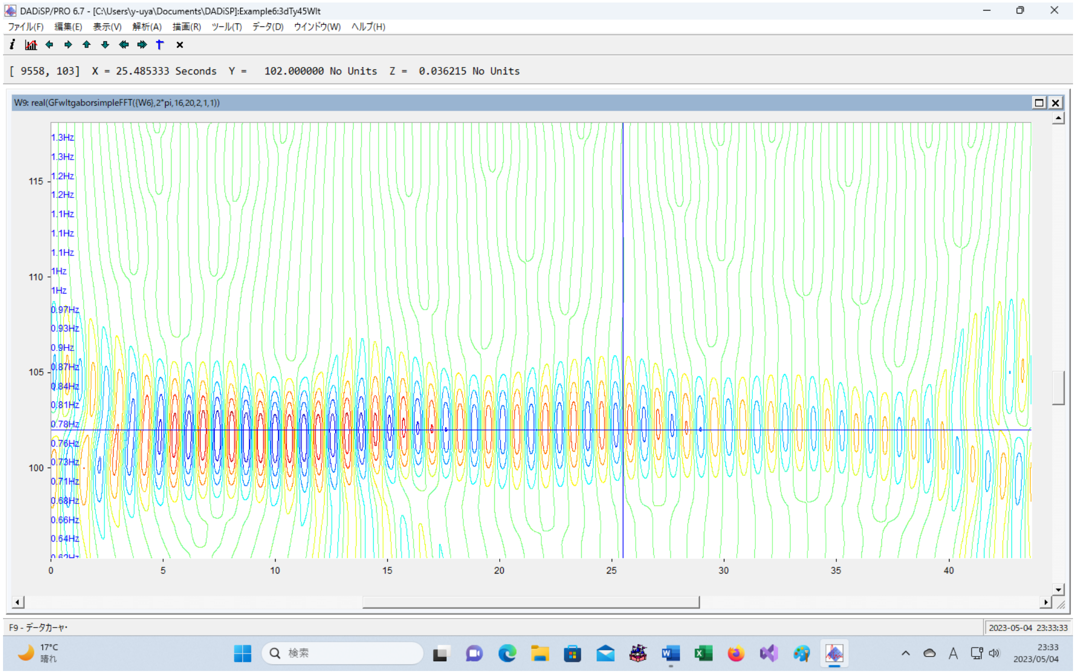


When I recorded the sound of the wind-turbine, I also filmed the wind-turbine spinning on video.
I measured the time it took for the blade to pass in front of the tower 21 times, and calculated the frequency based on that.
The frequency variation is consistent with the frequency variation in the wavelet analysis.

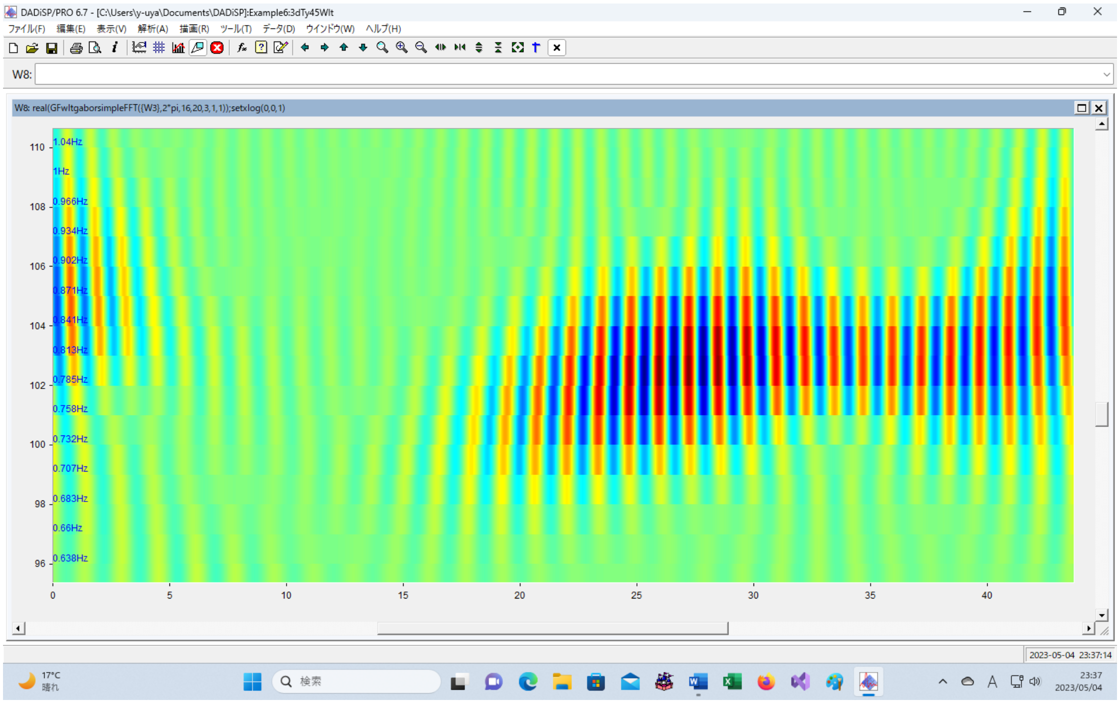
7回転		
21回通過	秒	周波数
21	28	0.75
21	22	0.95
21	23	0.91
21	23	0.91
21	24	0.88
21	27	0.78
21	30	0.70
21	24	0.88
21	26	0.81
21	25	0.84
21	26	0.81
21	26	0.81
21	26	0.81
21	26	0.81
21	27	0.78
21	31	0.68
21	31	0.68
21	27	0.78
21	26	0.81
21	25	0.84
21	26	0.81
21	28	0.75
21	28	0.75
	平均	0.80

Temporal fluctuations in frequencies around 0.8 Hz are examined by wavelet analysis.

From the following graph, we can see that it fluctuates between 0.73 Hz and 0.80 Hz, centered on 0.77 Hz.



In the following graph, you can see that the fluctuation is large, and the frequency fluctuates between 0.71Hz~0.94Hz.



When there is a constant wind speed and the wind-turbine has the function of keeping the rotation speed constant,

The frequency at which the sound pressure is maximized is determined by the number of times the blade passes in front of the tower and the time it takes.

Frequency number f = pass back N ÷ time T

In a wind-turbine with three blades, if the number of revolutions is R, the number of passes is 3*R=N, and the time in between is T.

f=R*3÷T

It can be said.

If R rotates in 1 minute, R*3÷60 = f, so the Ministry of the Environment used to say

The fundamental frequency f (Hz) is when the number of revolutions of the blades is R (rpm) and the number of blades is Z (sheets).

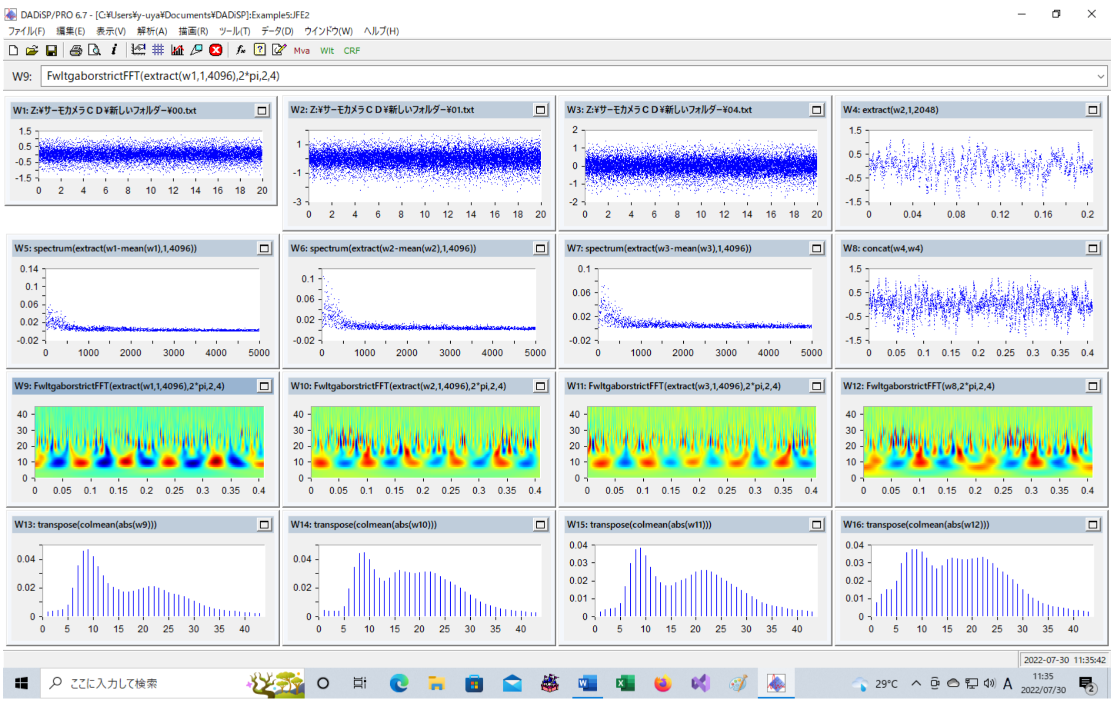
f =RZ/60 (Hz)

is correct.

When the frequency spectrum is calculated, the sound pressure is the peak value at the average value of 0.8 Hz in the above table.

Next is the noise at JFE's plants. Combining Wavelet Analysis with Chaos Theory,

JFE2



and

You can find a machine that is out of order. It is suitable for studying the noise in the room.

(A module for Wavelet analysis is required.))

2.6 Wind-turbine sounds in 164 locations nationwide

Of course, it has also been measured in other wind-turbines.

Measurement results of wind turbine sound at 164 locations nationwide

If the scale on the horizontal axis is a linear scale and the scale on the vertical axis is a Pascal value, it can be seen that extremely low-frequency sound from wind turbines with similar characteristics was measured at 164 wind-turbines surveyed in Japan a long time ago.

The following graph shows the "Response to Noise Generated by Wind Power Generation Facilities."

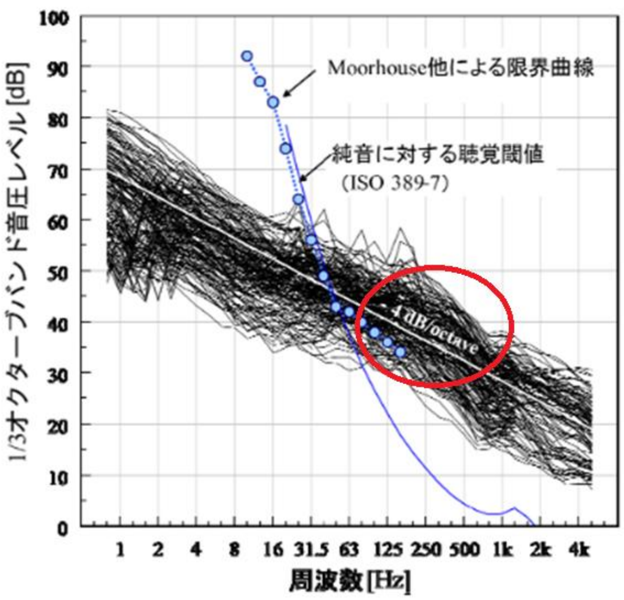


図 3　全国 29 の風力発電施設周辺 164 地点における風車騒音の周波数特性の分析結果

If you look closely at Figure 3, you can see that it is written as -4dB/octave in white letters.

"A **sound that doubles the frequency ratio based on a certain sound**" is called "a sound one octave higher".

When the frequency is doubled, it increases by one octave. An increase of one octave reduces the sound pressure level by 4 dB.

As a series in which the frequency is doubled,

0.5Hz, 1Hz, 2Hz, 4Hz, 8Hz, 16Hz、...

In the graph above, we use the value of the 1/3 octave band sound pressure level. To make the calculations easier, we will convert it to a 1/1 octave band.

The sound pressure level is determined by the sum of the sound energy belonging to each frequency band.

0.5～1Ｈｚ、１～2Ｈｚ、2～4Ｈｚ、４～8Ｈｚ、8～16Ｈｚ、… Using the value of the energy displayed in dB, 164 curves are drawn.

In terms of the white diagonal line that takes the middle of them, it will be a table like the one below.

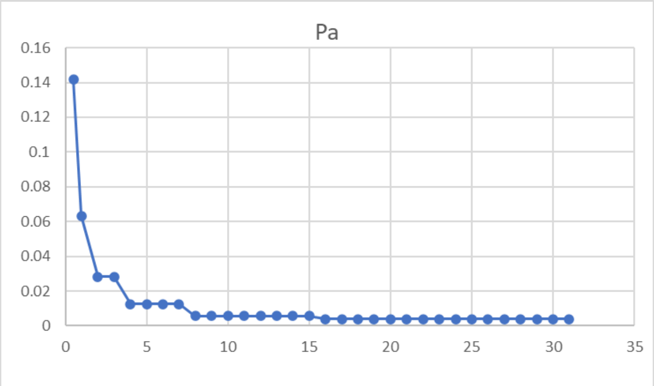
Hz	0.5	1	2	3	4	5	6	7	8
dB	74	70	66		62				58
Σ (Pa*Pa)	0.010048	0.004	0.001592		0.000634				0.000252
Pa*Pa/Hz	0.020095	0.004	0.000796	0.000796	0.000158	0.000158	0.000158	0.000158	3.15E-05
Hz	0.5	1	2	3	4	5	6	7	8
Pa	0.141757	0.063246	0.028217	0.028217	0.012589	0.012589	0.012589	0.012589	0.005617

The converted value of energy in the frequency band of 0.5 Hz or more and less than 1 Hz is 74 dB
The converted value of energy in the frequency band of 1 Hz or more and less than 2 Hz is 70 dB
The converted value of energy in the frequency band of 2 Hz or more and less than 4 Hz is 66 dB
The converted value of energy in the frequency band above 4 Hz and below 8 Hz is 62 dB
… Are.

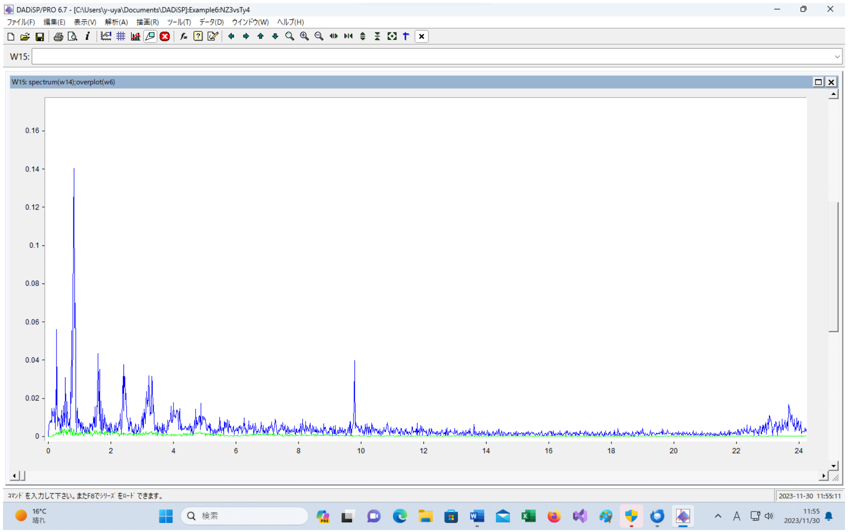
This energy is evenly distributed according to the linear coordinate scale, and then converted to the corresponding Pascal value, resulting in the number at the bottom of the table.

If you make the graph in Figure 3 a table and convert the value to a Pascal value, the graph will look like this.

Hz	dB	Σ (Pa*Pa)	Pa*Pa/Hz	Hz	Pa
0.5	74	0.0100475	0.020095091	0.5	0.141757
1	70	0.004	0.004	1	0.063246
2	66	0.0015924	0.000796214	2	0.028217
3			0.000796214	3	0.028217
4	62	0.000634	0.000158489	4	0.012589
5			0.000158489	5	0.012589
6			0.000158489	6	0.012589
7			0.000158489	7	0.012589
8	58	0.0002524	3.15479E-05	8	0.005617
9			3.15479E-05	9	0.005617
10			3.15479E-05	10	0.005617
11			3.15479E-05	11	0.005617
12			3.15479E-05	12	0.005617
13			3.15479E-05	13	0.005617
14			3.15479E-05	14	0.005617
15			3.15479E-05	15	0.005617
16	58	0.0002524	1.57739E-05	16	0.003972
17			1.57739E-05	17	0.003972



The graph on the right is very similar in shape to the blue line in the chart below.



Also, between 100 Hz and 4 kHz,

Hz	dB	Σ (Pa*Pa)	Pa*Pa/Hz	Hz	Pa
128	46	1.592E-05	1.24408E-07	128	0.000353
256	42	6.34E-06	2.4764E-08	256	0.000157
512	38	2.524E-06	4.92935E-09	512	7.02E-05
1024	34	1.005E-06	9.81206E-10	1024	3.13E-05
2048	30	0.0000004	1.95313E-10	2048	1.4E-05
4096	26	1.592E-07	3.88777E-11	4096	6.24E-06

The figures in Figure 3 vary depending on the wind turbine.
The following table shows the following table for high and low sound pressures around 1 kHz and 2 kHz.

Hz	dB	Σ (Pa*Pa)	Pa*Pa/Hz	Hz	Pa
1024	38	2.524E-06	2.46468E-09	1024	4.96E-05
1024	34	1.005E-06	9.81206E-10	1024	3.13E-05
1024	15	1.265E-08	1.23526E-11	1024	3.51E-06
2048	35	1.265E-06	6.17632E-10	2048	2.49E-05
2048	30	0.0000004	1.95313E-10	2048	1.4E-05
2048	12	6.34E-09	3.09549E-12	2048	1.76E-06

This means that the infrasound measured at Windy Hill, even when the microphone is not hit by the wind, was measured at all 164 locations nationwide.

Chapter 3 Basics of Noise Analysis

3.1 Basic terminology (Referred to the Lion website) ）

Effective value

For a periodic function $f(t)$, it has period T.

$$Effective\ value\ of\ f(t) = \sqrt{\frac{1}{T}\int_0^T (f(t))^2 dt}$$

In the case, $f(t) = Asin\omega t$. T=$2\pi/\omega$.

$$Effective\ value\ of\ Asin\omega t = \sqrt{\frac{1}{T}\int_0^T (Asin\omega t)^2 dt} = A/\sqrt{2}$$

Sound Pressure and Sound Pressure Level

Sound Pressure

Sound travels through the air as coarse waves. The pressure of the air changes compared to the pressure of the air when there is no sound (static pressure) compared to this static pressure when there is sound.

The change in pressure from this static pressure is the sound pressure. The unit is Pascals (Pa). The pressure of the gas when a force of 1 Newton is applied per 1 m^2 is 1 pascal.

Sound Intensity

At one point in the sound field, the sound energy that passes through a unit area in a unit of time is called the intensity of the sound (written as I or J). The unit is (W/m^2)

J=(p*p)/(ρ c) (W/m^2)

Here, p (Pa) is the sound pressure, ρ is the density of the air (kg / m^3), c is the speed of sound (m / s), and the product ρ c is called the acoustic impedance of the air, which is $\rho c \approx 400$ [NS / m 3].

Speed of sound

c $= \sqrt{\gamma P/\rho}$

γ Specific heat ratio(Ratio of constant pressure specific heat to constant product specific heat (Pa)、P Atmospheric pressure(Pa)、 ρ is the density of the air(kg/m^3)

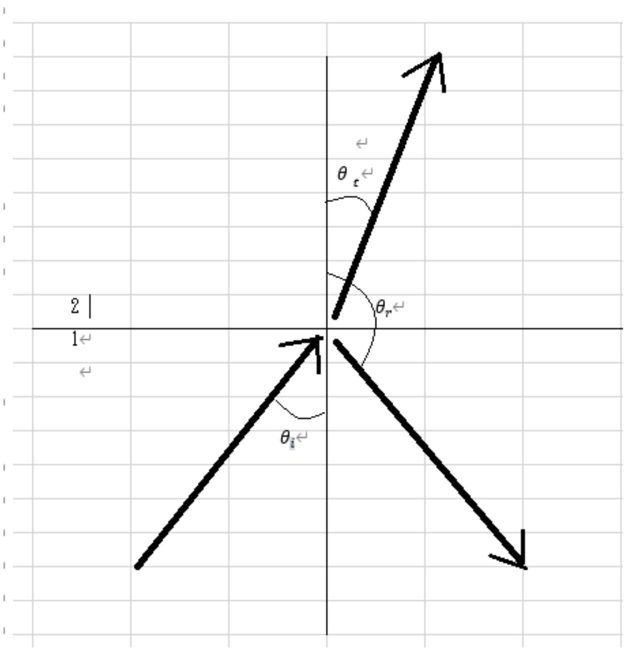
Sound pressure level

Compared with the reference sound pressure ($p_0$20 μPa = 20 * 10^(-6) = 2 * 10^(-5) (Pa)), the value obtained as follows

$L_p = 10 * \log (\frac{p^2}{p_0^2})$

where p is the sound pressure and is the sound pressure level. L_p

Reflection, transmission, absorb



When a plane wave hits the boundary of two types of media 1 and 2, part of it is reflected and part is transmitted.

Let the angle of incidence, reflection, and refraction be $\theta_i, \theta_r, \theta_t$.

Sound reflection

Consider the case where the angle of incidence when the plane wave hits the boundary is 0. θ_i

If the intrinsic acoustic resistance is $\rho_1 c_1$、 $\rho_2 c_2$, in $\theta_i = 0$.

The sound pressure reflectance is (sound pressure of reflected wavesp_r) / (sound pressure of incident wavesp_i),

$$\frac{p_r}{p_1} = \frac{\rho_2 c_2 - \rho_1 c_1}{\rho_1 c_1 + \rho_2 c_2}$$

Become.

The energy reflectance of sound isr_0

$$\frac{p_r^2}{p_i^2} = r_0 = \left(\frac{\rho_1 c_1 - \rho_2 c_2}{\rho_1 c_1 + \rho_2 c_2}\right)^2$$

Are.

$\theta_i \neq 0$. If the energy reflectance is$r$

$$\frac{p_r^2}{p_i^2} = r \quad = \left(\frac{\rho_1 c_1 cos\theta_t - \rho_2 c_2 cos\theta_i}{\rho_1 c_1 cos\theta_t + \rho_2 c_2 cos\theta_i}\right)^2$$

(cf. Principal of optics, Max Born and Emil Wolf, p42)

Sound Transmission

For the transmission of sound, the intrinsic acoustic resistance , $\rho_1 c_1$、 $\rho_2 c_2$, . $\theta_i = 0$ In the case of

The sound pressure transmittance is (sound pressure of transmitted waves p_t) / (sound pressure of incident waves p_i),

$$\frac{p_t}{p_i} = \left(\frac{2\rho_2 c_2}{\rho_1 c_1 + \rho_2 c_2}\right)$$

The energy transmittance of sound is t_0

$$\frac{p_t^2}{p_i^2} = t_0 = \frac{4\rho_1 c_1 \rho_2 c_2}{(\rho_1 c_1 + \rho_2 c_2)^2}$$

$\theta_i \neq 0$. The energy transmittance of the sound in the case of t

$$t \quad = \frac{4\rho_1 c_1 \rho_2 c_2 cos\theta_t cos\theta_i}{(\rho_1 c_1 cos\theta_t + \rho_2 c_2 cos\theta_i)^2}$$

(cf. Principal of optics, Max Born and Emil Wolf, p43)

Refraction of sound

If the speed of sound in medium 1 is and the speed of sound in medium 2 is , $c_1 c_2$

$$\frac{sin\theta i}{c_1} = \frac{sin\theta t}{c_2}$$

and this is called Snell's law.

If there is a temperature difference in the atmosphere and there is a difference in the density of the air, the sound will change the direction of travel.

The temperature of the atmosphere is usually lower in the upper atmosphere, so the degree is high, and the speed of sound

$c = \sqrt{\gamma P/\rho}$

γ Specific heat ratio(Ratio of constant pressure specific heat to constant product specific heat (Pa)、P Atmospheric pressure(Pa)、 ρ is the density of the air(kg/m^3)

will be smaller. Therefore, the sound emitted from near the earth's surface takes a course toward the sky. In winter, when the temperature of the earth's surface is lower than in the sky, the sound emitted near the surface of the earth takes a course toward the ground.

Sound absorption coefficient, transmission loss

At an actual boundary, such as a wall, some of the energy of the sound is lost. The remaining energy of the reflected sound absorbed and transmitted at the boundary surface, The energy of the transmitted sound, the energy of the incident sound, $I_r I_t I_i$

Determine the reflectance r as r=I_r/. I_i

Sound absorption coefficient α

$$\alpha = 1 - r = (I_i - I_r)/I_i$$

Transmittance τ to

$$\tau = I_t/I_i$$

Transmission Loss TL to

$$TL = 10\log(1/\tau)$$

I decide.

Distance attenuation

Radiated sound from the sound source, diffuse as the shape of a globe or as hemisphere.

The strength of the sound decreases according to the distance. In the case the distance is very long, absorb by air and the shape of ground occur, this decrease added to geometrical decrease.

This decrease called excess attenuation

Point sound source

In a free space, a point source of a sound with sound power p(W) exist, the power of the sound I (W/m^2) at the point where the distance from source is r (m), is given by next formula

$$I = p/4\pi r^2$$

Whne the point source is set on the graound,

$$I = p/2\pi r^2$$

The relation sund power level L_W (dB) and sound pressure level L_p (dB),

Free space,

$$L_p = L_W - 20logr - 11$$

On the graoud

$$L_p = L_W - 20logr - 8$$

From above foromula,

$$20\log(2r) = 20(log2 + logr) = 20logr + 20 * 0.301.3 = 20logr + 6.0206$$

When the distance is twice, sound pressure level decrease 6 (dB).

Line sound source

The sound source is straight line, the sound spred like a cylinder,

In a free space, a point source of a sound with sound power p(W) exist, the power of the sound I (W/m^2) at the point where the distance from source is r (m), is given by next formula

$$I = p/2\pi r$$

Whne the point source is set on the graound,

$$I = p/\pi r$$

The relation sund power level L_W (dB) and sound pressure level L_p (dB),

Free space,

$$L_p = L_W - 10logr - 8$$

On the graoud

$$L_p = L_W - 10logr - 5$$

From above foromula,

$$10\log(2r) = 10(log2 + logr) = 10logr + 10 * 0.301.3 = 20logr + 3.013$$

When the distance is twice, sound pressure level decrease 3 (dB).

In the case of finite length, if the distance from source is less than (the length of sound source.) * ($1/\pi$), we treat as line source, if the distance more far, we treat is as point source.

Surface sound source

When infinite number of point sound source spread to the plane, we call it surface sound source. In this case, the sound not decrease.

If the shape of sound source is rectangle, the distance from the source is less (length short side) * ($1/\pi$), sound not decrease.

From the distance to the distance (length of long side) * ($1/\pi$), we treat it as line sound source. In the case more far, we treat it as point sound source.

Sound absorption

When the sound propagates in the air, main factor the decrease is expansion of wave surface. In the case of large distance, sound absorption by air occurs. This relates to the temperature, humidity, sound frequency.

In the case of plane sound source, there is no expansion of the sound surface, the sound loss it's energy, the energy changes to the heat energy of the air.

The relation with frequency,

$$P = P_0 e^{-\alpha x}$$

P_0 is energy of the source, $P = P_0 e^{-\alpha x}$ is the energy at distance x.

α is attenuation constant, it's value in the air is $\alpha = 2.0 \times 10^{-11} \nu^2$,

the value of α in the sea, $\alpha = 2400 \times 10^{-15} \nu^2, (8 * 300 = 2400)$. ν is number of vibration.

	平面波で波面の広がりにより減衰が無い場合					（P0＝1とした場合）			
		周波数Hz							
		1	20	200	500	1000	2000	5000	8000
距離m	1000	1.00000	0.99999	0.99920	0.99501	0.98020	0.92312	0.60653	0.27804
	2000	1.00000	0.99998	0.99840	0.99005	0.96079	0.85214	0.36788	0.07730
	3000	1.00000	0.99998	0.99760	0.98511	0.94176	0.78663	0.22313	0.02149
	4000	1.00000	0.99997	0.99681	0.98020	0.92312	0.72615	0.13534	0.00598
	5000	1.00000	0.99996	0.99601	0.97531	0.90484	0.67032	0.08208	0.00166

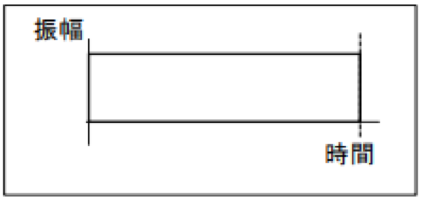
As for the attenuation of sound due to the conversion of air molecules into thermal energy, there is no change for sounds with frequencies below 20 Hz even after a distance of 5km.

Even in the case of low-frequency sound of 20 Hz or less, if the waveform is spherical or cylindrical, attenuation due to the spread of the wavefront occurs.

Window function

We use window function, when calc the spectrum().

(1) Rectangle



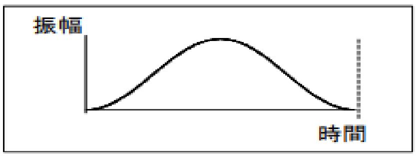
All signals in the time frame, pass the frame without any change.

This is same, that we don’t use window function.

This window is suitable for a pulse.

The leakage occurs, by the discontinuity.

(2) Hanning

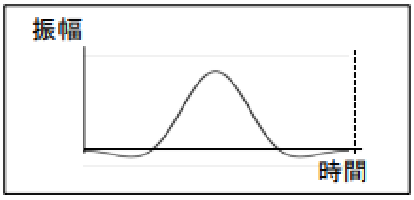


Typical window, the start and end point of the signal changed to zero.

The slope is moderate.

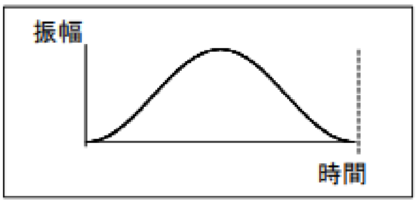
This is suitable for sound and vibration, which is the sampling data of continuous data.

(3) Flat top



The graph of spectrum(), near the peak point, the shape is flat. The frequency resolution is not sharp, the graph is shoutable for read the height of peak point.

(4) Hamming



Similar to Hanning window, the slope is more steep than Hanning window. When used Hamming window, the result value is almost same to the value of Rion’s software.

When calculated using a Hamming window, the numerical value can be obtained to be close to the analysis result by Rion's software.

How to take the average

There are cases where several frame times do not overlap, or there are cases where frame times are staggered by about half and overlapped. Taking the average gives you smooth data.

・Matters to be confirmed with Lion

The manual for the Lion NL-62 states:

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

There is a formula that says.

This means that (i=1,..,N) can be obtained $P_A(i)$ by approximating the G characteristic in a physical network.

ISO7196 Description: "Remarks: The G-characteristics can be physically approximated by a simple network consisting of an inductor/resistor/capacitor. The A-weighted sound pressure level for each measurement time is directly obtained according to the above equation, and the result is used to obtain the overall A-weighted sound pressure level by the above equation.

When I checked with Lion, I was told that in the case of a sampling frequency of 48 kHz, the value of can be obtained 48,000 per second, but they did not disclose how it was determined.$P_A(i)P_A(i)$

Based on the manual, it seems that the calculation is based on the sound pressure data measured in 0.25 seconds or the sound pressure data measured in 1 second. In the case of a sampling frequency of 48 kHz, in the case of 0.25 seconds, the minimum frequency is 4 Hz because it is calculated from 12000 data, and in the case of 1 second, it is calculated from 48000 data, so the minimum frequency is 1 Hz.$P_A(i)$

In the calculation of the A characterization, it is possible to get by with 1 Hz or more, but it is difficult to do so with the G characteristic that handles extremely low frequency sound.

The frequency of low-frequency sound generated by large wind turbines today is around 0.5 Hz to 0.8 Hz.

In the ISO7196, the center frequency is set from 0.25 Hz to 315 Hz. Since the bandwidth at 0.25 Hz is 0.0575 Hz, it must be calculated using at least 20 seconds of data.

Since the amount of computation increases and a lot of memory is used, it is necessary to analyze the data recorded with the flatness characteristics (Z characteristics) using a PC to investigate the characteristics of the sound of wind turbines. If the calculation is based on the sound pressure data recorded with this flatness characteristic, the frequency spectrum corresponding to the fingerprint of the wind-turbine can be obtained.

By adding the NX-42WR waveform recording program to the Lion's NL-62 precision sound level meter, you can create a recorded WAV file using 16-bit signed integers.

The frequency weighting at the time of recording is Z-characteristic (flat characteristic), the sampling rate is 48 kHz, and if you record about 1 minute as a continuous recording time, you can measure from 0.01667 Hz to 24 kHz.

The NX-42WR waveform recording program from Lion allows for two types of bits to use for a single integer value when recording to a file: a 24-bit signed integer and a 16-bit signed integer.

In this case, we are dealing with the case of 16-bit.

First of all, there is the following explanation of signed integers.

Range that can be represented by a signed integer

When using two's complement for negative numbers, an 8-bit signed integer can have values in the range -128 ~ 127.

Similarly, a 16-bit signed integer can have a value in the range – 2^15 ~ 2^15 -1, and a 32-bit signed integer can have a value in the range – 2^31 ~ 2^31 -1.

In both cases, the number of negative numbers is increased by one.

Now, as for the integer expression of the measured value,

In the case of 16-bit,

As for the range of sound pressure that can be measured with a sound level meter, the maximum sound pressure that can be measured with a sound level meter (with low-frequency sound measurement function) is described in the NL-62 instruction manual as a maximum of 148 dB.

In the section on display and output full scale, it is written that the full scale of the output voltage can be set up to 70dB ~ 130dB in 10dB increments.

Here, when 130dB is selected, the WAV file is named

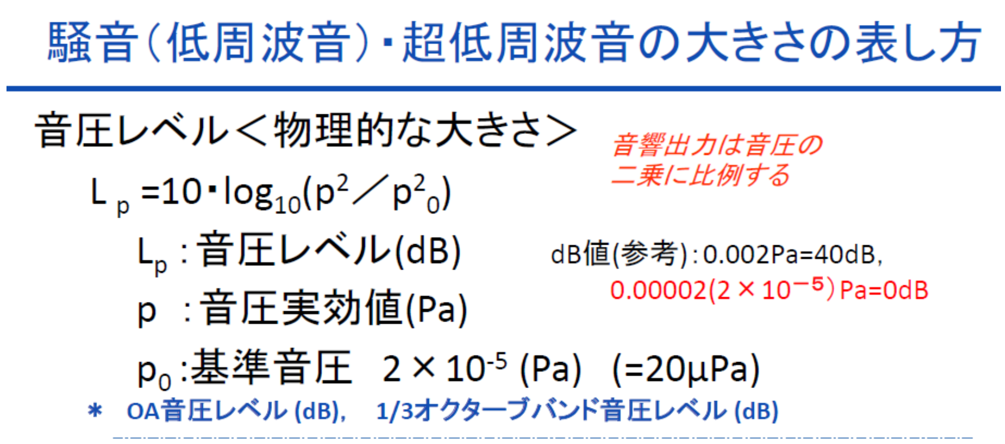
NL_001_20220503_111400_130dB_0008_0000_ST0001

From the middle part of the name, you can see that the full scale of the output voltage is set to 130 dB.

The data recorded in the wav file is designed to handle a slightly larger sound pressure, and the displayed output full-scale value of +13 dB is the full-scale value of the WAVE file.

Therefore, even if the setting is 130 dB, the actual full-scale value in the WAVE file is 143 [dB], which corresponds to 2×10^(-5)×10^(143/20) = 282.5075116 [Pa].

The reason is



than $L_p = 10*\log_{10}(p^2/p_0^2) = 20*\log_{10}(p/p_0)$

and

$143 = 20 * \log_{10}(p/(2*10^{-5}))$

$p/(2*10^{-5}) = 10^\wedge(143/20)$

$p = (2*10^{-5}) * 10^\wedge(143/20)$ =282.5075116Pa(RMS)

This is because it will be.

The value of 282.5075116 Pa (143 dB) as an effective value is described in the wav file differs depending on the file.

A 16-bit signed integer is in the range {+2^(15)-1} ~ -2^15, and the integer -2^15 = -32768 corresponds to the case where the sound pressure is -282.5075116Pa.

In the case of 16 bits, the integer value 1 means the sound pressure (rms) of 282.5075116Pa/ {2^(15)} =8.621445056*10^(-3), so the integer value k is k*821445056*10^(-3) Pa (rms)

Means

The Lion sample data file is NL_001_20100101_000146_090dB_0001_0000_SL0001 and

You can see that the data is a 16-bit signed integer, and the display output full-scale value, 90 dB, is selected and measured. In addition, the data recorded in the WAV file is designed so that it can handle a little larger sound pressure.

(The displayed output full-scale value of +13dB is the full-scale value of the WAVE file.))

Therefore, the full-scale value of the WAVE file: 103 [dB], and the Pascal value of this is 2×10^(-5)×10^(103/20) = 2.825075116 [Pa].

－2.825075116 Corresponds [Pa] to -2^15=-32768.

(-2.825075116Pa / {-(2^(15))})=8.621445056*10^(-5)

Therefore, the integer value k means k * 8.621445056 * 10^ (-5) Pa (rms value)

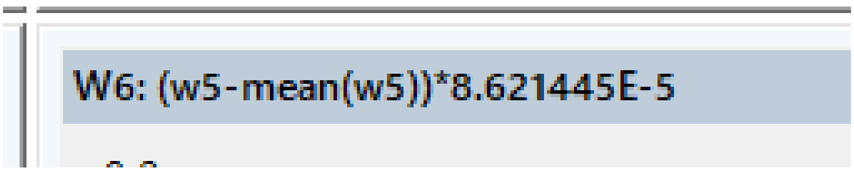
This number, 8.621445056*10^(-5), is determined by the number of bits in the signed integer and the setting of the display output full-scale value.

If the calculations are troublesome, you can use the AS-70 (trial version is free.) and perform the following operations.

Display - The value of Value/Bit (8.621445E-5) can be used as the file information.

and convert it using the value of Value/Bit here, and it becomes a Pascal value (effective value).

Make sure that the input range item is 90dB.



Since it is convenient to calculate the Wavelet, I subtracted the average value in W2. To adjust to the Pascal value, we set it to *8.621445E-5. This value (8.621445E-5) was verified using an AS-70.

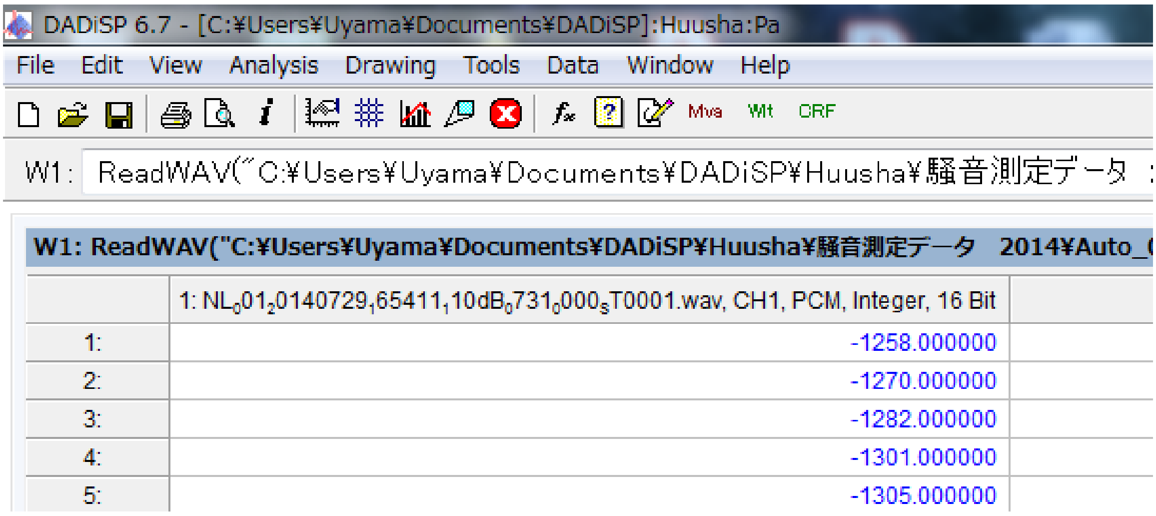
To convert an integer value to a Pascal value, you need to look closely at the file name or use AS-70.

Caution:

If you select the display output full-scale value of 110 dB, the display output full-scale value of +13 dB becomes the full-scale value of the WAVE file.

Therefore, the full-scale value of the WAVE file: 123 [dB], and the Pascal value of this is 2×10^(-5)×10^(123/20) = 28.25 [Pa]. (28.25Pa / {2^(15)}) =8.621445056*10^(-4)

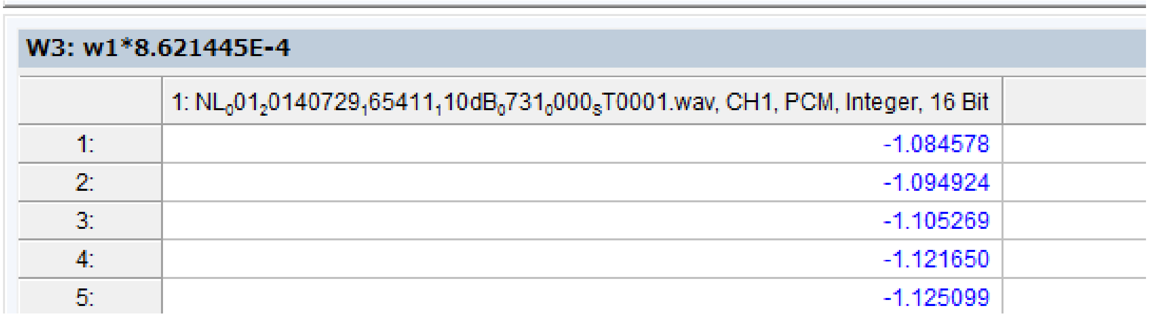
At this time, when the wav file is displayed with DADISP, the integer value in 16 bits is the following value.



	1: NL_01_20140729_65411_10dB_0731_000_ST0001.wav, CH1, PCM, Integer, 16 Bit
1:	-1258.000000
2:	-1270.000000
3:	-1282.000000
4:	-1301.000000
5:	-1305.000000

Multiplying the Value/Bit value of 8.621445E-4 bys:

You will get the following numbers:



	1: NL_01_20140729_65411_10dB_0731_000_ST0001.wav, CH1, PCM, Integer, 16 Bit
1:	-1.084578
2:	-1.094924
3:	-1.105269
4:	-1.121650
5:	-1.125099

This value is the Pascal value (rms).

There is a difference between this number and the graph display in the Rion software AS-70. When I checked with Lyon, I found that

When we checked the WAVE file, the 5th line from the top is this number.

The unit is Pa (rms value).

-1.084578

-1.094924

-1.105269

-1.12165

-1.125099

Question 1 "Checking Pascal values with AS-70".

I think that you have confirmed the WAVE waveform by graphing it with AS-70.

On the AS-70 software, characteristic numerical values (maximum value, minimum value) are selected and thinned according to the magnification of the waveform.

Since the thinning rate changes depending on the expansion rate, it is not possible to say what number it

is.
If you want to check the numbers that have not been thinned, please check the data output as a CSV file in the WAVE file.
Therefore, it may not match the graph display of other waveform analysis software.

That was it.

3.2 Meaning of FFT

Fundamentals of noise analysis (Referenced by Lion materials) ）

What is the meaning of FFT and what is the premise of it?

Let's take a look at the basic concepts that underlie FFT.

Functional Analysis （Kosaku Yosida）p86 has a

4. The Orthogonal Base, Bessel's Inequality and Parseval's Relation

Definition 1. A set S of vectors in a pre-Hilbert space X is called an orthogonal set, if x⊥y for each pair of distinct vectors x, y of S. If, in addition, |x|=1 for each x ∈ S, then the set S is called an ortho-normal set. An orthogonal set S of a Hilbert space X is called complete orthogonal system or an orthogonal base of X, if no orthogonal set of X contains S as proper subset.

Theorem 1. A Hilbert space X (having a non -zero vector) has at least one complete orthonormal system. Moreover, if S is any orthonormal set in X, there is a complete orthonormal system containing S as a subset.

Theorem 2. Let $S = \{x_\alpha; \alpha \in A\}$ be a complete orthogonal system of a Hilbert space X. For any $f \in X$, we define its Fourier coefficients (with respect to S)

$$f_\alpha = (f, x_\alpha)$$

Then we have Parseval's relation

$$|f|^2 = \sum_{\alpha \in A} |f_\alpha|^2$$

Corollary 1. We have the Fourier expansion

$$f = \sum_{j=1}^{\infty} f_{\alpha j} x_{\alpha j} = s\text{-}\lim_{n\to\infty} \sum_{j=1}^{n} f_{\alpha j} x_{\alpha j}$$

Corollary 2. Let $l^2(A)$ be the space $L^2(A, B, m)$ where m({α})=1 for every point α of A. Then the Hilbert space X is isometrically isometric to the Hilbert space $l^2(A)$ by the correspondence

$$X \ni f \leftrightarrow \{f_\alpha\} \in l^2(A)$$

In the sense that

$(f+g) \leftrightarrow \{f_\alpha + g_\alpha\}$, $\beta f \leftrightarrow \{\beta f_\alpha\}$, and $|f|^2 = |\{f_\alpha\}|^2 = \sum_{\alpha \in A} |f_\alpha|^2$

Example. $\left\{\frac{1}{\sqrt{2\pi}} e^{int}; n = 0, \pm 1, \pm 2, \dots\right\}$ is a complete orthogonal system in the Hilbert space $L^2(0,2\pi)$

Therefore, if we add a few conditions to , we can express the function as an infinite series of trigonometric functions.$e^{i\theta} = cos\Theta + i\, sin\Theta L^2(0,2\pi)$

Since it is impossible to handle infinite series in computer calculations, it is necessary to perform approximate calculations using discretized data, and FFT is a technology that performs the calculation at high speed.

Fourier transform and FFT

Discrete Fourier transform

For a discrete signal x(n), a function of ω

$$X(\omega) = \sum_{-\infty}^{\infty} x(n)e^{-in\omega}$$

is called the Fourier transform of x(n). This is the substitution of z in the z transformation.$e^{i\omega}$

If a circle of radius 1 centered at the origin (unit circle) is included in the preceding annular region, the integral path is taken on the unit circle. When it is ,$z = e^{i\omega} dz = ie^{i\omega} d\omega = izd\omega$

x (n) = (1/(2 π i)) X (z) zn−1 dz (Line integral on a closed curve in an annular region)

$x(n) = \frac{1}{2\pi i} \oint X(z)z^{n-1}dz$ (Line integral on a closed curve in an annular region)

$$= \frac{1}{2\pi i} \int_{-\pi}^{\pi} X(\omega)e^{in\omega - i\omega} izd\omega \quad = \frac{1}{2\pi} \int_{-\pi}^{\pi} X(\omega)e^{in\omega}d\omega$$

is established.

According to the theory about the Fourier series,

$$\sum_{-\infty}^{\infty} |x(n)|^2 < \infty$$

If is true, then the equality of the Perseveral

$$\frac{1}{2\pi} \int_{-\pi}^{\pi} |X(\omega)|^2 d\omega = \sum_{-\infty}^{\infty} |x(n)|^2$$

is established.

Let's consider this Fourier transform with the following conditions: First, if x(n) is 0 except n=0, 1, 2, . . . , N-1, then the series is

$$X(\omega) = \sum_{n=0}^{N-1} x(n)e^{-in\omega}$$

It comes to.

Originally, the ω in this equation changes continuously, but we will only consider the following finite number of ω values.

$\omega_k = \frac{2\pi k}{N}$ (k=0, 1, 2, . . . , N-1)

And then

$$X(\omega_k) = \sum_{n=0}^{N-1} x(n)e^{-in\omega_k} \quad = \sum_{n=0}^{N-1} x(n)e^{-\frac{in2\pi k}{N}}$$

It comes to.

In addition

$$W_N = e^{-\frac{i2\pi}{N}}$$

If you say,

$$X(\omega_k) = \sum_{n=0}^{N-1} x(n){W_N}^{nk}$$

I will multiply it. To express the expression symmetrically, let be . And then$X(k) = X(\omega_k)$

$X(k) = \sum_{n=0}^{N-1} x(n) {W_N}^{nk}$ (k=0,1,2,...,N-1)

It comes to. This transformation is called the discrete Fourier transform (DFT).

The inverse transformation of this discrete Fourier transform is possible,

$x(n) = \frac{1}{N} \sum_{n=0}^{N-1} X(k) {W_N}^{-nk}$ (n=0,1,2,...,N-1)

is established. This is called the discrete Fourier inverse transformation (IDFT).

The fact that the equation for this inverse transformation holds is that

$(W_N)^k = e^{-\frac{i2\pi k}{N}} = 1$

Note that this is only the case when k is an integer multiple of N.

From now on

X(k) = X(k+Nt), x(n) = x(n+Nt) t=..,-2,-1,0,1,2,..

is true, i.e., the period is N.

- 2.3.2 FFT

First, let's consider the content of the DFT. If you change the symbol slightly to express DFT,

N complex data f(0),f(1),f(2),⋯,f(N-1)

In contrast with

N complex data F(0),F(1),F(2),⋯,F(N-1)

to be corresponded to in the following way.

$F(n) = \sum_{k=0}^{N-1} f(k) e^{-\frac{i2\pi nk}{N}}$ (n=0,1,2,⋯,N-1)

It takes quite a bit of time to perform this calculation. If N is in the form of a power of 2, it can be calculated efficiently by special ingenuity. The DFT in this special case is called the FFT.

To think about what DFT means, it's easier to think of it as a case where it's close to continuous data.

1024 numbers

sin(2 π k/1024) (k=0,1,2,...,1023)

Let's examine the results of FFT for .

Calculated as N=1024,

$$F(n) = \sum_{k=0}^{N-1} sin(2\pi k/N) e^{-\frac{i2\pi nk}{N}} = \frac{N}{2\pi} \sum_{k=0}^{N-1} \frac{2\pi}{N} sin(2\pi k/N) \{\cos\left(\frac{2\pi kn}{N}\right) - i * sin(\frac{2\pi kn}{N})\}$$

In the case of n<<N, it can be approximated by integrals.

$$F(n) = \frac{N}{2\pi} \{\int_0^{2\pi} \sin(x) \cos(nx) dx - i \int_0^{2\pi} \sin(x) \sin(nx) dx\}$$

So, if we calculate F(1) by paying attention to the orthogonality of trigonometric functions,

$$F(1)=\frac{N}{2\pi}\{\int_0^{2\pi}\sin(x)\cos(x)dx\ -i\int_0^{2\pi}\sin(x)\sin(x)dx\}$$

$=\frac{1024}{2\pi}\{-i\int_0^{2\pi}\sin(x)\sin(x)dx\}$ $=\frac{1024}{2\pi}\left\{-i\int_0^{2\pi}\frac{1}{2}(1-\cos(2x))dx\right\}=\frac{1024}{2\pi}\{-i\frac{2\pi}{2}\}$=-512i

It comes to.

Let's say that the first sequence consists of N sampled values of the function f(x).

This f (x) can be expressed as a finite sum of Fourier series with a periodic function,

$$f(x)=\frac{1}{2}a_0+\sum_{m=1}^{t}\{a_m\cos\left(\frac{x2\pi m}{N}\right)+b_m\sin\left(\frac{x2\pi m}{N}\right)\}$$

Suppose it is.

In the case of n<t<<N,

$$f(x)=\frac{1}{2}a_0+\sum_{m=1}^{t}\{a_m\cos\left(\frac{x2\pi m}{N}\right)+b_m\sin\left(\frac{x2\pi m}{N}\right)\}$$

For the result of FFT for , we can convert it to an integral and use trigonometric orthogonality.

$F(n)=\sum_{k=0}^{N-1}f(k)e^{-\frac{i2\pi nk}{N}}$ (n=0, 1, 2, …, N−1)

$$F(n)=\sum_{k=0}^{N-1}\{\frac{1}{2}a_0+\sum_{m=1}^{t}\{a_m\cos\left(\frac{k2\pi m}{N}\right)+b_m\sin\left(\frac{k2\pi m}{N}\right)\}e^{-\frac{i2\pi nk}{N}}$$

$$=\frac{N}{2}(a_n-ib_n)$$

Therefore, we can see that the real part indicates the existence of a cos wave and the imaginary part indicates the existence of a sin wave, and that the coefficient is (N/2) times.

If n is close to N/2, it means the presence of a high-frequency component, but it cannot be interpreted directly by integration.

However, if n is close to N, we can think of it as follows:

exp(i2π Nk/N)=1, so

F(n)＝Σf(xk)exp(-i2π nk/N)

＝Σf(xk)exp(-i2π nk/N) exp(i2π Nk/N)

＝Σf(xk)exp(i2π (N-n)k/N)

＝{Σf(xk)cos(2π (N-n)k/N)} + i{Σf(xk)sin(2π (N-n)k/N)}

F(N-n)＝Σf(xk)exp(-i2π (N-n)k/N)

＝{Σf(xk)cos(2π (N-n)k/N)} - i{Σf(xk)sin(2π (N-n)k/N)}

Therefore, for F(N-n)

F(n)＝a＋bi　ならば、F(N-n)＝a－bi

Therefore, F(N-n) is a conjugate complex number (mirror image) of F(n).

It is necessary to consider the existence of each frequency component by focusing on the left half of the graph.

As a further absolute value, we find the absolute value. $\frac{N}{2}F(n) = (a_n - ib_n)$(The absolute value is and is the amplitude when the trigonometric function is combined.))$\sqrt{(a_n^2+b_n^2}$

And to display only the left half of the graph of this absolute value, spectrum(). This gives you an idea of the strength of the frequency component.

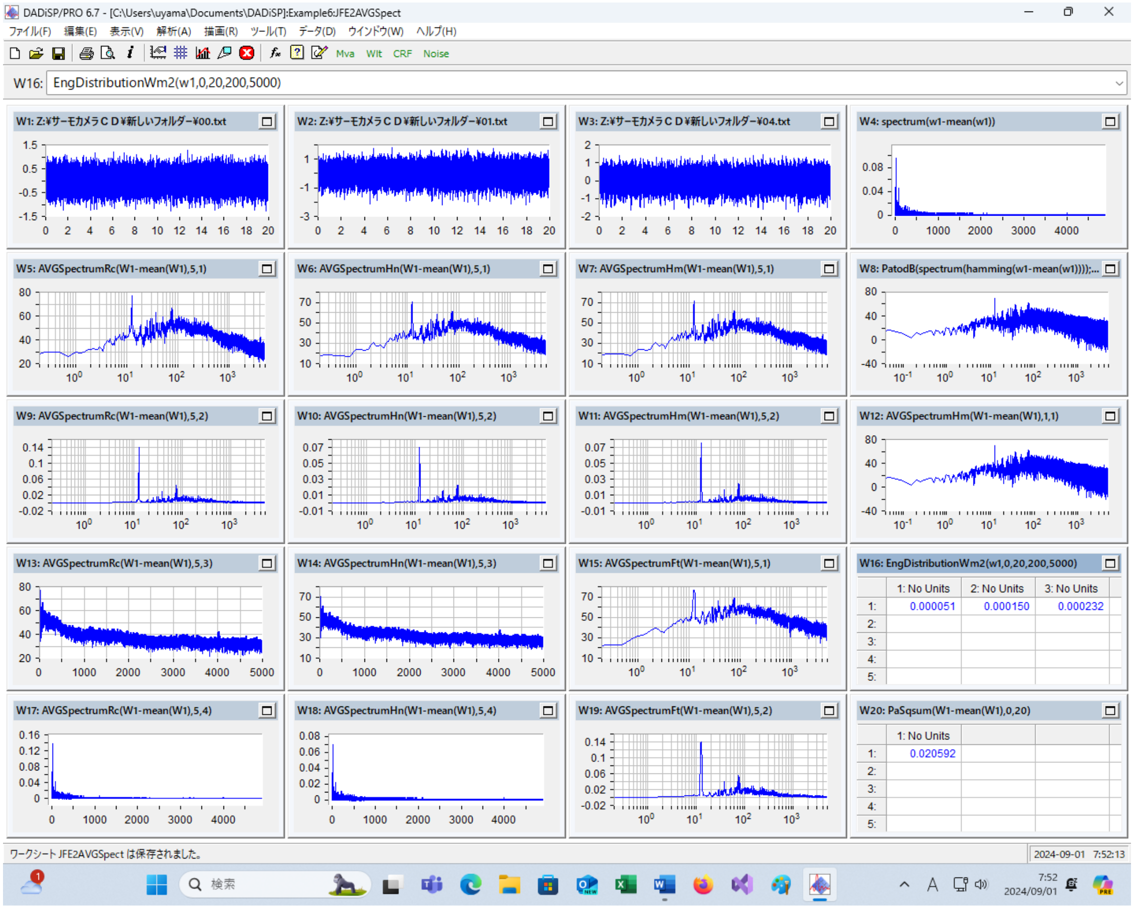
The presence and strength of the frequency component are determined using the numerical value of the calculation result of spectrum().

・Sound Pressure Spectrum Calculation and display

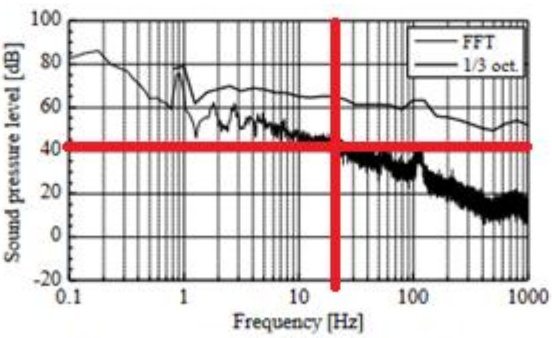
The following graph shows the frequency spectrum of the sound pressure of the sound in JFE's steel mills.

It is calculated by setting the window function and the number of times of the average.

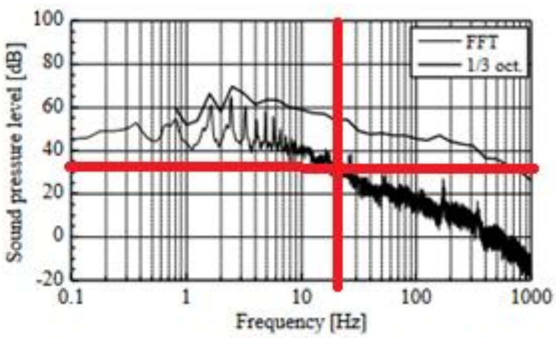
JFE2AVGSpect



"[Project Title: S2-11 Research on the Evaluation of the Effects of Wind Power Generation on Humans]" has a graph of the spectrum of sound pressure in decibels.

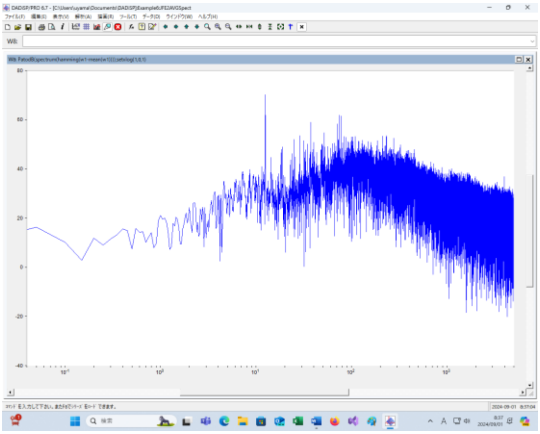


図(2)-11 図(2)-9の音圧のスペクトル

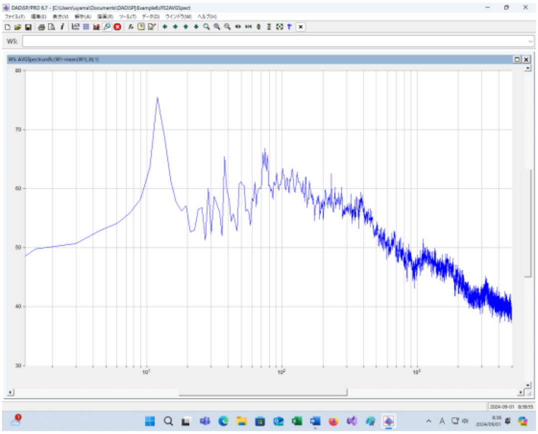


図(2)-12 図(2)-10の音圧のスペクトル

If you simply find the frequency spectrum and correct it to a decibel value, it will be as follows, and the right side will become thicker.



So, if you calculate the frequency spectrum 30 times to get the average value, and then change it to a decibel display, you get a smart graph.



・Distribution of energy

Sound Intensity

At one point in the sound field, the sound energy that passes through a unit area in a unit of time is called the intensity of the sound (written as I or J). The unit is (W/m²)

J=(p*p)/(ρc) (W/m²)

The following table calculates the intensity of the sound (W/m2) when the sound of the factory passes through the microphone.

W16: EngDistributionWm2(w1,0,20,200,5000)

	1: No Units	2: No Units	3: No Units	4: No Units
1:	0.000051	0.000150	0.000232	0.000433
2:				

0～20Hz 0.000051 (W/m2)

20～200Hz 0.000150 (W/m2)

200～5000Hz 0.000232 (W/m2)

0～5000Hz 0.000433 (W/m2)

Traffic noise in front of Lion is about 10^(-5)

W15: EngDistributionWm2(w6,0,20,200,24000)

	1: No Units	2: No Units	3: No Units	4: No Units
1:	1.757791E-007	8.079829E-008	1.805011E-005	1.830650E-005
2:				

0～20Hz 1.757791E-007 (W/m2)

20～200Hz 8.079829E-008 (W/m2)

200～24000Hz 1.805011E-005 (W/m2)

0～24000Hz 1.830650E-005 (W/m2)

The % indication of the intensity of the sound is

W12: w15*100/max(w15)

	1: No Units	2: No Units	3: No Units	4: No Units
1:	0.960200	0.441364	98.599449	100.000000
2:				

It comes to.

Near the wind-turbine when the wind is light, about 10^ (-4)

W15: EngDistributionWm2(w2,0,20,200,24000)				
	1: No Units	2: No Units	3: No Units	4: No Units
1:	2.432890E-004	2.138726E-005	1.627290E-007	2.648317E-004
2:				

In the vicinity of wind-turbines when the wind is strong, it is about 10^(-3)

W9: EngDistributionWm2(w8,0,20,200,24000)				
	1: No Units	2: No Units	3: No Units	4: No Units
1:	1.492656E-003	2.285370E-005	6.942087E-008	1.515570E-003
2:				

3.3 1/3 octave analysis

The frequency range and center frequency in the 1/3 octave analysis are as follows.

	1/3オクターブバンド中心周波数と帯域幅						
x	x/3	2^(x/3)	厳密中心周波数 1000*2^(x/3)	f 1	f 2	帯域幅	公称中心周波数
37	-12.3333	0.000194	0.194	0.173	0.218	0.045	0.194
36	-12	0.000244	0.244	0.218	0.274	0.057	0.250
35	-11.6667	0.000308	0.308	0.274	0.345	0.071	0.315
34	-11.3333	0.000388	0.388	0.345	0.435	0.090	0.400
33	-11	0.000488	0.488	0.435	0.548	0.113	0.500
32	-10.6667	0.000615	0.615	0.548	0.691	0.142	0.630
31	-10.3333	0.000775	0.775	0.691	0.870	0.179	0.800
30	-10	0.000977	0.977	0.870	1.096	0.226	1.000
29	-9.66667	0.00123	1.230	1.096	1.381	0.285	1.250
28	-9.33333	0.00155	1.550	1.381	1.740	0.359	1.600
27	-9	0.001953	1.953	1.740	2.192	0.452	2.000
26	-8.66667	0.002461	2.461	2.192	2.762	0.570	2.500
25	-8.33333	0.0031	3.100	2.762	3.480	0.718	3.150
24	-8	0.003906	3.906	3.480	4.385	0.905	4.000
23	-7.66667	0.004922	4.922	4.385	5.524	1.140	5.000
22	-7.33333	0.006201	6.201	5.524	6.960	1.436	6.300
21	-7	0.007813	7.813	6.960	8.769	1.809	8.000
20	-6.66667	0.009843	9.843	8.769	11.049	2.279	10.000
19	-6.33333	0.012402	12.402	11.049	13.920	2.872	12.500
18	-6	0.015625	15.625	13.920	17.538	3.618	16.000
17	-5.66667	0.019686	19.686	17.538	22.097	4.559	20.000
16	-5.33333	0.024803	24.803	22.097	27.841	5.743	25.000
15	-5	0.03125	31.250	27.841	35.077	7.236	31.500
14	-4.66667	0.039373	39.373	35.077	44.194	9.117	40.000
13	-4.33333	0.049606	49.606	44.194	55.681	11.487	50.000

12	-4	0.0625	62.500	55.681	70.154	14.473	63.000
11	-3.66667	0.078745	78.745	70.154	88.388	18.234	80.000
10	-3.33333	0.099213	99.213	88.388	111.362	22.974	100.000
9	-3	0.125	125.000	111.362	140.308	28.945	125.000
8	-2.66667	0.15749	157.490	140.308	176.777	36.469	160.000
7	-2.33333	0.198425	198.425	176.777	222.725	45.948	200.000
6	-2	0.25	250.000	222.725	280.616	57.891	250.000
5	-1.66667	0.31498	314.980	280.616	353.553	72.938	315.000
4	-1.33333	0.39685	396.850	353.553	445.449	91.896	400.000
3	-1	0.5	500.000	445.449	561.231	115.782	500.000
2	-0.66667	0.629961	629.961	561.231	707.107	145.876	630.000
1	-0.33333	0.793701	793.701	707.107	890.899	183.792	800.000
0	0	1	1000.000	890.899	1122.462	231.563	1000.000
-1	0.333333	1.259921	1259.921	1122.462	1414.214	291.752	1250.000
-2	0.666667	1.587401	1587.401	1414.214	1781.797	367.584	1600.000
-3	1	2	2000.000	1781.797	2244.924	463.127	2000.000
-4	1.333333	2.519842	2519.842	2244.924	2828.427	583.503	2500.000
-5	1.666667	3.174802	3174.802	2828.427	3563.595	735.168	3150.000
-6	2	4	4000.000	3563.595	4489.848	926.253	4000.000
-7	2.333333	5.039684	5039.684	4489.848	5656.854	1167.006	5000.000
-8	2.666667	6.349604	6349.604	5656.854	7127.190	1470.335	6300.000
-9	3	8	8000.000	7127.190	8979.696	1852.507	8000.000
-10	3.333333	10.07937	10079.368	8979.696	11313.708	2334.012	10000.000
-11	3.666667	12.69921	12699.208	11313.708	14254.379	2940.671	12500.000
-12	4	16	16000.000	14254.379	17959.393	3705.013	16000.000
-13	4.333333	20.15874	20158.737	17959.393	22627.417	4668.024	20000.000
-14	4.666667	25.39842	25398.417	22627.417	28508.759	5881.342	

3.4 A-weighted sound pressure level

Noise is a nuisance that humans feel with their ears.

$$L_p = 10 * \log\left(\frac{p^2}{p_0^2}\right)$$

Even if the Lp in the above equation is the same, even if it feels annoying with a high frequency, it will not be so annoying with a low frequency sound, so in order to obtain a numerical value that shows the annoyance of the noise felt by humans, it is necessary to compensate for each frequency for Lp. That is the weighting by the A-characteristic.

The numerical value that expresses the annoyance of noise for humans is the A-weighted sound pressure level (unit is decibel dB). In this calculation, considering that the audible range of human hearing is 20 Hz to 20000 Hz and that the annoyance felt by humans (the amount of noise perceived by hearing) varies depending on the frequency, the overall noise level (dB) is calculated by weighting each frequency band.

The center frequency of the frequency band to be calculated (considered only in the case of 1/3 octave analysis) is called A-characteristic (1/3 octave band weighting characteristic), but there are various weighting standards.

6.3hz to 20kHz standard

(IEC61672:2014 standard) (Functions Weight1d3A(ww,w)) and NoiseLevel1d3A(ww,w) This standard)

Frequency [Hz]	A-Weighting	C-Weighting	Z-Weighting
6.3	-85.4	-21.3	0.0
8	-77.8	-17.7	0.0
16000	-6.6	-8.5	0.0
20000	-9.3	-11.2	0.0

10 Hz to 20 kHz standard

In JIS C 1509, (the functions Weight1d3A10Hz(ww,w) and NoiseLevel1d3A10Hz(ww,w) are specified in this standard)

●周波数重み付け特性 A/C/Z の値

JIS C1509 に規定された周波数重み付け特性 A/C/Z の値とそのグラフを表 1、図 2 に示します。

表 1　周波数重み付け特性 A/C/Z　(1/3 オクターブバンド)

No	公称周波数（Hz）	厳密周波数（Hz）	A 特性（dB）	C 特性（dB）	Z 特性（dB）
10	10	10.00	-70.4	-14.3	0.0
11	12.5	12.59	-63.4	-11.2	0.0
42	16000	15848.93	-6.6	-8.5	0.0
43	20000	19952.62	-9.3	-11.2	0.0

20Hz to 20kHz standard

On Ono Sokki's website, (the functions Weight1d3A20Hz(ww,w) and NoiseLevel1d3A20Hz(ww,w) are in this standard)

A

A特性の補正値を列記します。補正値は「JIS C 1509」に記載されています。フラットの値（dB）に下記の値を加算してください。

周波数（Hz）	補正値（dB）
20	-50.5
25	-44.7
16000	-6.6
20000	-9.3

About Center Frequency

The nominal frequency is the center frequency of each 1/3 octave band, expressed as a sharp frequency.

The exact frequency is the exact center frequency value of each band obtained by Equation (1) with the band number n as an integer of 10~33.

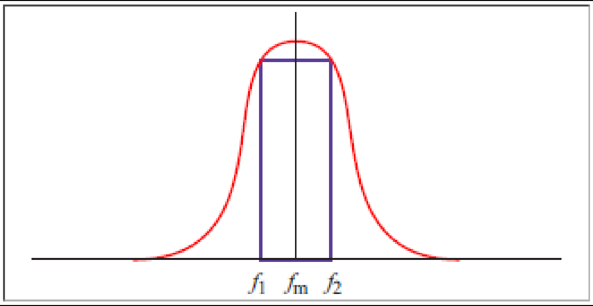
$$f = 1000 \times 10^{0.1\times(n-30)} \quad [\mathrm{Hz}] \qquad \cdots\cdots (1)$$

(n=10,f=10,　n=13,f= 19.95262315, ,　n=33,f= 1995.262315)

In this program, we are using the nominal frequency.

Characteristics of Bandpass Filters

The characteristics of the bandpass filter for the above center frequencies are as follows:



$$f_2 = \sqrt[3]{2} \cdot f_1$$

$$f_m = \sqrt{f_1 \cdot f_2} = \sqrt[6]{2} \cdot f_1 = \frac{f_2}{\sqrt[6]{2}}$$

$$\left(\sqrt[3]{2} = 1.2599、\sqrt[6]{2} = 1.1225\right)$$

バンド幅：$B = (f_2 - f_1) \approx 0.23 f_m$

図 11-2　1/3 オクターブバンドにおける中心周波数、上下限周波数とバンド幅

The attenuation in its vicinity is

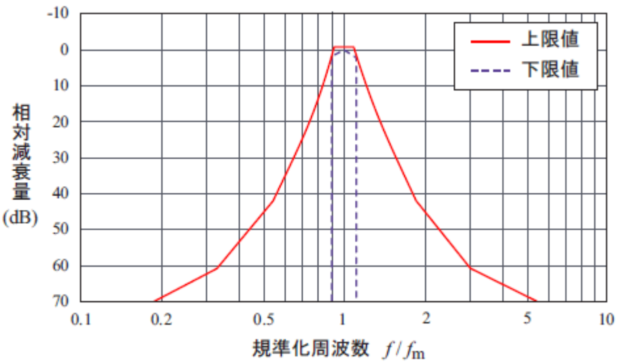


図 11-5　1/3 オクターブバンドフィルタ クラス 1 の相対減衰量の限界値

It has become.

The graph of weighting in the A characteristic is as follows.

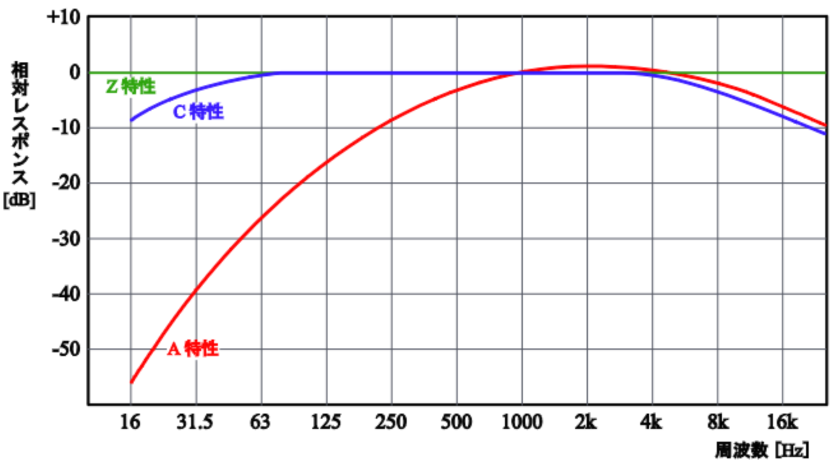


図 2　周波数重み付け特性 A/C/Z

An example of the calculation that clearly shows the meaning of weighting is the material of the Acoustics Subcommittee of the Technical Research Group of the Japan Construction Federation.

	オクターブバンド中心周波数 (Hz)						
	63	125	250	500	1k	2k	4k
① ● 道路騒音の例	70.8	69.0	68.7	65.8	63.8	59.2	53.3
② A特性の重み付け	−26.2	−16.1	−8.6	−3.2	0.0	1.2	1.0
③ ○ A特性重み付け後(①+②)	44.6	52.9	60.1	62.6	63.8	60.4	54.3
騒音レベル(下式参考)	68.3						

[dB]

$$L_A = 10\log_{10}(10^{L_{A63}/10} + 10^{L_{A125}/10} + 10^{L_{A250}/10} + 10^{L_{A500}/10} + 10^{L_{A1k}/10} + 10^{L_{A2k}/10} + 10^{L_{A4k}/10})$$

ここで、L_A：騒音レベル(dB)、L_{A63}～L_{A4k}：63 Hz～4 kHz 帯域の A 特性の重み付け後の音圧レベル(dB)

Comparing the above calculation example with the graph of weighting in the A characteristic, In the table of calculation examples,

The example value of road noise at 1 kHz is 63.8 (dB) and the A-weighting weight is 0.0. In the graph of weighting with A characteristics, it corresponds to the fact that the curve representing the A characteristic intersects with a horizontal line with a response (dB) of 0 at 1 kHz.

The example value for road noise at 63 Hz is 70.8 (dB) and the A-weighting is -26.2. In the graph of weighting with A characteristics, it corresponds to the fact that the curve representing the A characteristic intersects with a horizontal line with a response (dB) of -26.2 at 63 Hz.L_P =

Therefore, a sound of 63 Hz is treated as a value of 44.6 (dB), even though it is 70.8 (dB) in terms of sound annoyance$L_P = L_A$ =.

The equation for obtaining the noise level (A-weighted sound pressure level) (dB) from the sound pressure weighted by the A-weight, which is the frequency weight corresponding to hearing, is as follows. $P_A L_A$

$$L_A = 10\log_{10}\frac{p_A^2}{p_0^2} = 20\log\frac{p_A}{p_0}$$

p_A：測定された周波数重みA付きの（瞬時）音圧の実効値

p_0：基準となる音圧の実効値（20μPa）（Paはパスカルという圧力単位）

$$L_p = 10 * log_{10}(P \quad /P_0)^2$$

AndP_0 $=2\times10^{-5}$、L_P =70.8、L_A =44.6

$$L_p = 70.8 = 10 * log_{10}(P_{70.8}/P_0)^2$$

The sound pressure of a sound of 70.8 (dB) at 63 Hz is 10^(70.8/20)=3467.37=$P_{70.8}/P_0$

$P_{70.8} = 3467.37 * (2 * 10^{-5})$=0.06935

$$L_A = 44.6 = 10 * log_{10}(P_{44.6}/P_0)^2$$

The sound pressure of a sound of 44.6 (dB) at 63 Hz is 10^(44.6/20)=169.8=$P_{70.8}/P_0$

$P_{44.6} = 169.8 * (2 * 10^{-5})$=0.003396

Here

$$-26.2 = 10 * log_{10}(P_{44.6}/P_{70.8})^2$$

is established. This is the correction value due to the A characteristic.

$$\frac{P_{44.6}}{P_{70.8}} = 10^{\left(\frac{-26.2}{20}\right)} = 0.0489$$

Therefore, the sound pressure is treated as if it has been multiplied by 0.0489.

Now, for the calculation of the overall noise level, check the following material.

【参考】：1/3 オクターブのデータより 1/1 オクターブのデータへの変換

既知の 1/3 オクターブデータの dB 値より対応する 1/1 オクターブバンドデータの dB 値へ変換するには、求めたい 1/1 オクターブバンドに対応する 1/3 オクターブバンドデータの dB 値の和を計算します。 例えば、1/1 オクターブの中心周波数 1000 Hz のバンドデータ値を求める場合、対応する 1/3 オクターブのバンドデータが次のような dB 値であるとき；

800 Hz	73 dB
1000 Hz	77 dB
1250 Hz	75 dB

；中心周波数 1000Hz の 1/1 オクターブバンド値は次の式から求められます。

$$10\log_{10}\left(10^{\frac{73}{10}}+10^{\frac{77}{10}}+10^{\frac{75}{10}}\right)=80\ (\mathrm{dB}) \qquad \text{式 11-7}$$

This calculation calculates the noise level relative to the sum of the sound energies in each frequency band.

Since the square of the sound pressure is proportional to the intensity (energy) of the sound, the magnitude of the energy in this band is ${P_{1/1}}^2$ If we consider the sum of the energies, consider (J = (p * p) / (ρ c) and multiply by an appropriate constant.)

$$(P_{800})^2+(P_{1000})^2+(P_{1250})^2={P_{1/1}}^2$$

is established.

$$L_{800}=10*log_{10}(P_{800}/P_0)^2$$

Than, therefore, $L_{800}/10=log_{10}(P_{800}/P_0)^2 ({}^{P_{800}}/_{P_0})^2=10^{L800/10}$

and

$$L_{1/1}=10*log_{10}(P_{1/1}/P_0)^2$$
$$=10*log_{10}(((P_{800})^2+(P_{1000})^2+(P_{1250})^2)/{P_0}^2)$$
$$=10*log_{10}\left(10^{L800/10}+10^{L1000/10}+10^{L1250/10}\right)$$

It comes to.

(In the created function, the bandwidth is determined for each center frequency, and the sound pressure is squared for the components in it.)
Then, the sum is taken and the value is treated as the square of the sound pressure of the center frequency.)

consequently

$$L_A=10\log_{10}(10^{L_{A63}/10}+10^{L_{A125}/10}+10^{L_{A250}/10}+10^{L_{A500}/10}+10^{L_{A1k}/10}+10^{L_{A2k}/10}+10^{L_{A4k}/10})$$

ここで、L_A：騒音レベル(dB)、L_{A63}～L_{A4k}：63 Hz～4 kHz 帯域の A 特性の重み付け後の音圧レベル(dB)

is calculated as the overall noise level using the noise level in each frequency band after weighting by the A characterization. Alternatively, it can be said that the noise level is calculated after considering the sum of energy.

The numeric value is

$$10*log_{10}\left(10^{L63/10}+10^{L125/10}+10^{L250/10}+10^{L500/10}+10^{L1000/10}+10^{L2000/10}+10^{L4000/10}\right)$$
$$10*log_{10}\left(10^{44.6/10}+10^{52.9/10}+10^{60.1/10}+10^{62.5}+10^{63.5/10}+10^{60.4/10}+10^{54.3/10}\right)$$

=68.34502291

This is the noise level of 68.3 in the calculation example.

According to the calculation example above, the calculation procedure is as follows:

Calculate the sound pressure (in Pascals) for each frequency band.

Compared with the reference sound pressure, the sound pressure level (in dB) in that frequency band is determined.

Each frequency band is weighted with an A-weight.

Based on the weighted values, the overall energy is calculated to obtain the overall sound pressure level (in dB).

It will be,

6.3hz to 20kHz standard, (IEC61672:2014 standard)

（function Weight1d3A(ww,w)）と NoiseLevel1d3A(ww,w) This standard）

10 Hz to 20 kHz standard, JIS C 1509

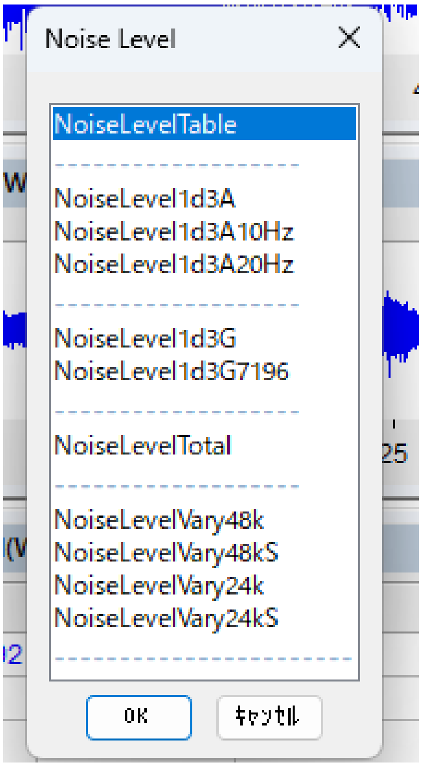
（function Weight1d3A10Hz(ww,w) と NoiseLevel1d3A10Hz(ww,w) This standard）

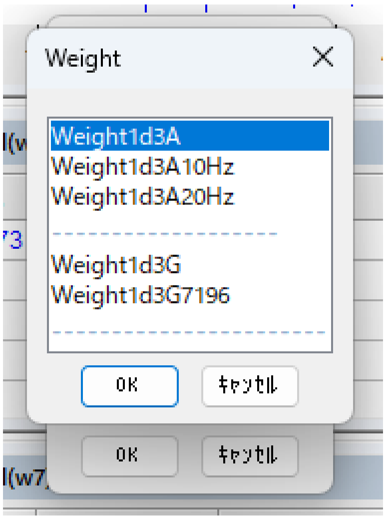
20Hz to 20kHz standard, Ono Sokki's HP

（function Weight1d3A20Hz(ww,w) と NoiseLevel1d3A20Hz(ww,w) This standard）

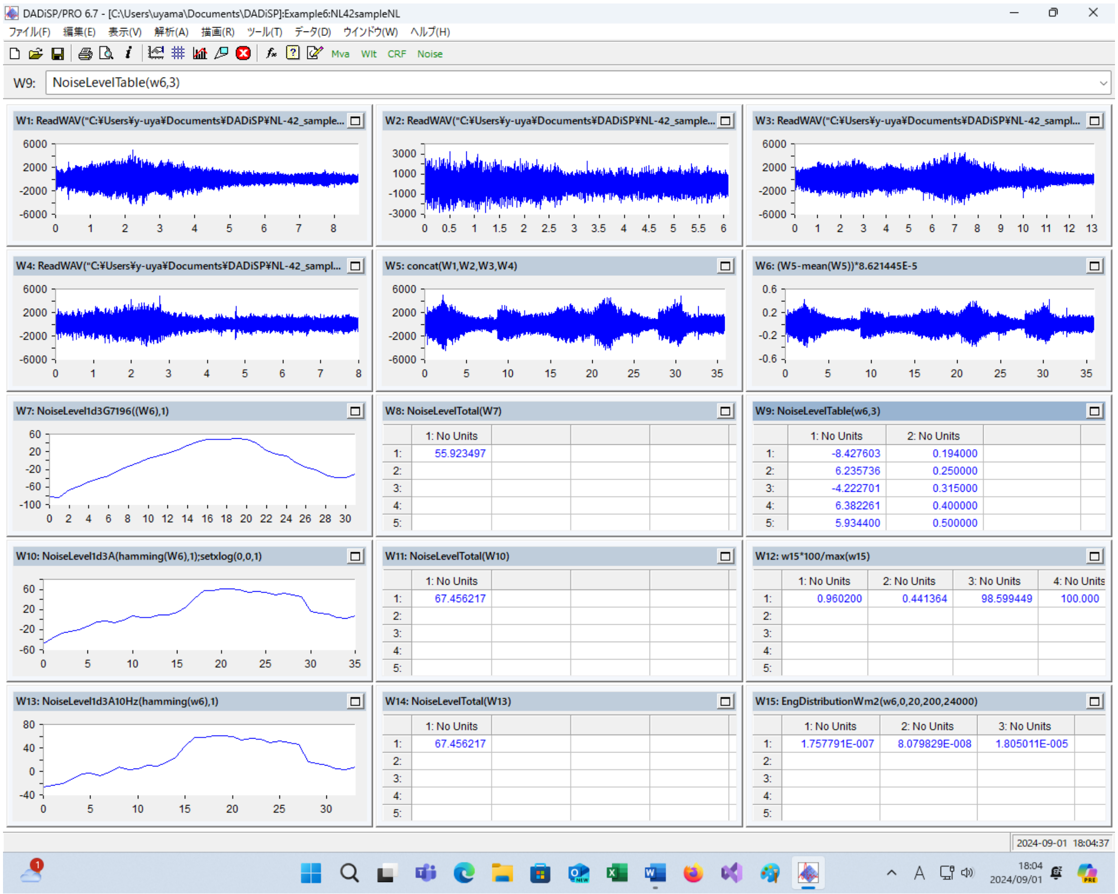
Center frequency from 6.3 Hz

	1/3オクターブバンド中心周波数と帯域幅（6.3～20000Hz）						
x	x/3	2^(x/3)	厳密中心周波数 1000*2^(x/3)	f 1	f 2	帯域幅	公称中心周波数
22	-7.33333	0.006201	6.201	5.524	6.960	1.436	6.300
21	-7	0.007813	7.813	6.960	8.769	1.809	8.000
20	-6.66667	0.009843	9.843	8.769	11.049	2.279	10.000
19	-6.33333	0.012402	12.402	11.049	13.920	2.872	12.500
18	-6	0.015625	15.625	13.920	17.538	3.618	16.000
17	-5.66667	0.019686	19.686	17.538	22.097	4.559	20.000
16	-5.33333	0.024803	24.803	22.097	27.841	5.743	25.000
15	-5	0.03125	31.250	27.841	35.077	7.236	31.500
14	-4.66667	0.039373	39.373	35.077	44.194	9.117	40.000
13	-4.33333	0.049606	49.606	44.194	55.681	11.487	50.000
12	-4	0.0625	62.500	55.681	70.154	14.473	63.000
11	-3.66667	0.078745	78.745	70.154	88.388	18.234	80.000
10	-3.33333	0.099213	99.213	88.388	111.362	22.974	100.000
9	-3	0.125	125.000	111.362	140.308	28.945	125.000
8	-2.66667	0.15749	157.490	140.308	176.777	36.469	160.000
7	-2.33333	0.198425	198.425	176.777	222.725	45.948	200.000
6	-2	0.25	250.000	222.725	280.616	57.891	250.000
5	-1.66667	0.31498	314.980	280.616	353.553	72.938	315.000
4	-1.33333	0.39685	396.850	353.553	445.449	91.896	400.000
3	-1	0.5	500.000	445.449	561.231	115.782	500.000
2	-0.66667	0.629961	629.961	561.231	707.107	145.876	630.000
1	-0.33333	0.793701	793.701	707.107	890.899	183.792	800.000
0	0	1	1000.000	890.899	1122.462	231.563	1000.000
-1	0.333333	1.259921	1259.921	1122.462	1414.214	291.752	1250.000
-2	0.666667	1.587401	1587.401	1414.214	1781.797	367.584	1600.000
-3	1	2	2000.000	1781.797	2244.924	463.127	2000.000
-4	1.333333	2.519842	2519.842	2244.924	2828.427	583.503	2500.000
-5	1.666667	3.174802	3174.802	2828.427	3563.595	735.168	3150.000
-6	2	4	4000.000	3563.595	4489.848	926.253	4000.000
-7	2.333333	5.039684	5039.684	4489.848	5656.854	1167.006	5000.000
-8	2.666667	6.349604	6349.604	5656.854	7127.190	1470.335	6300.000
-9	3	8	8000.000	7127.190	8979.696	1852.507	8000.000
-10	3.333333	10.07937	10079.368	8979.696	11313.708	2334.012	10000.000
-11	3.666667	12.69921	12699.208	11313.708	14254.379	2940.671	12500.000
-12	4	16	16000.000	14254.379	17959.393	3705.013	16000.000
-13	4.333333	20.15874	20158.737	17959.393	22627.417	4668.024	20000.000





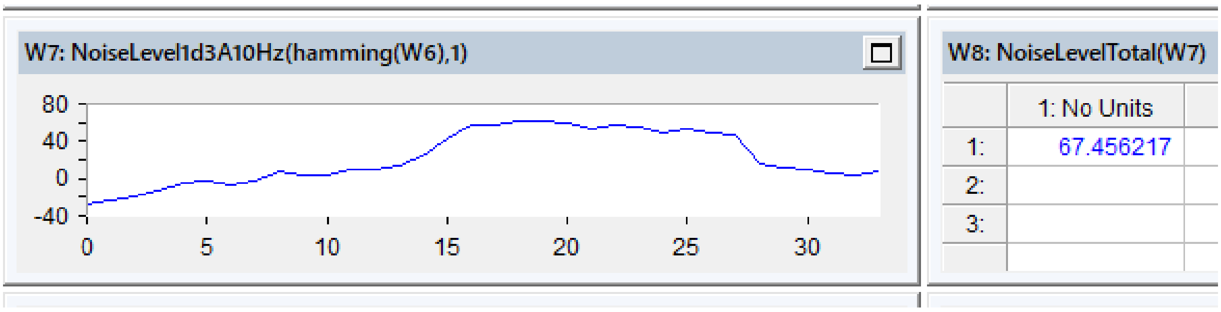
NL42SampleNL



W5 : NoiseLevelTotal(NoiseLevel1d3G(hamming(w2),1,1))

Even so, it will be the same number.

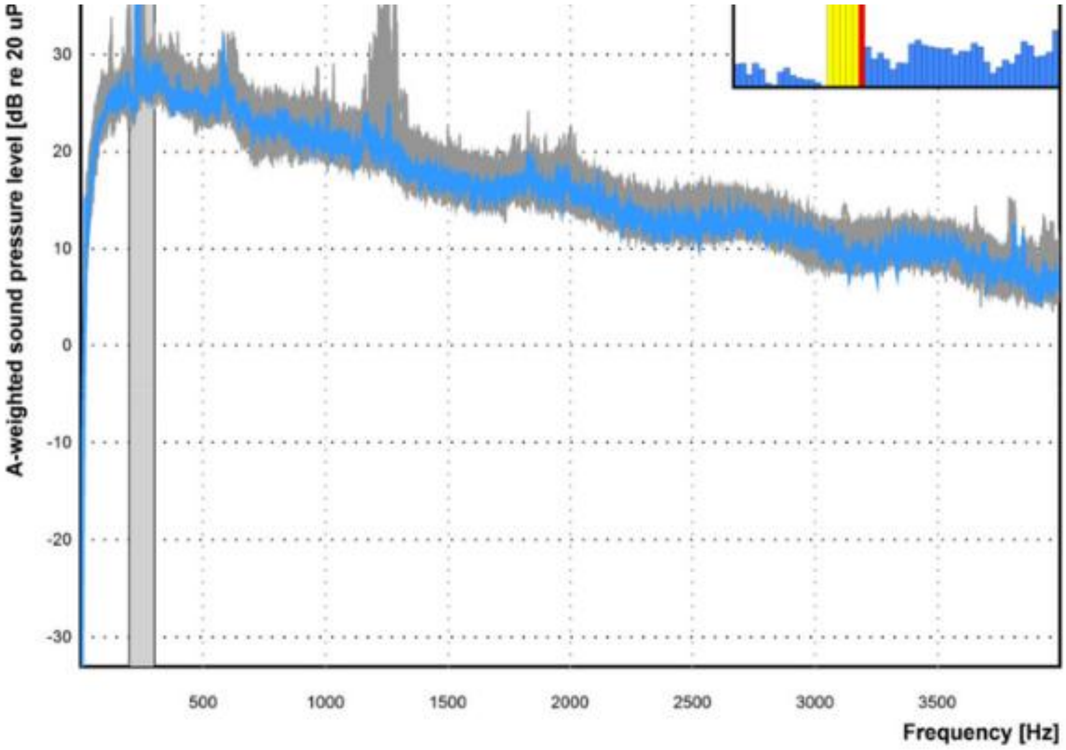
If we treat the 38-second data as a whole and calculate the noise level at the A weight, we get 67.456217 dB.



・Excluded sound processing using A-characteristics

A-weighted sound pressure level [dB]

Some people claim that the graph below is the "FFT analysis result".

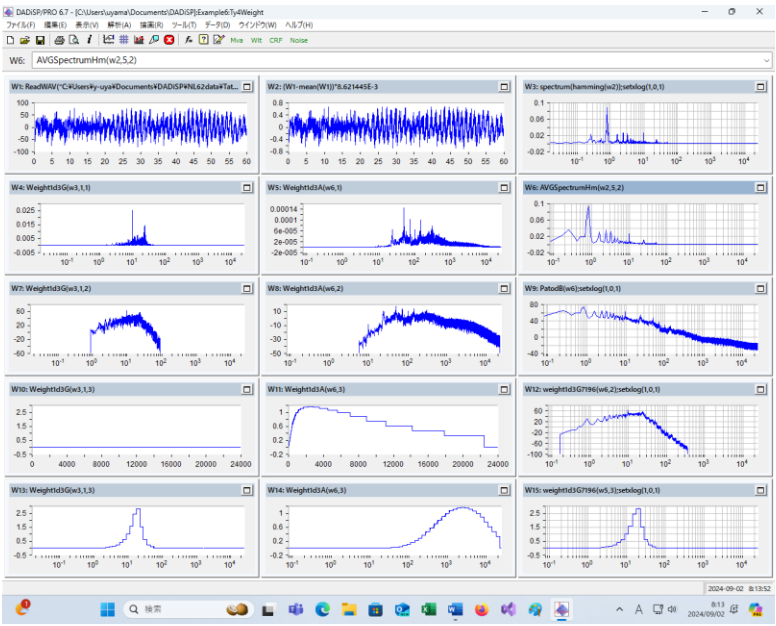


注）グラフ中の灰色の帯で示す箇所（臨界帯域）の詳細を右上に示す。

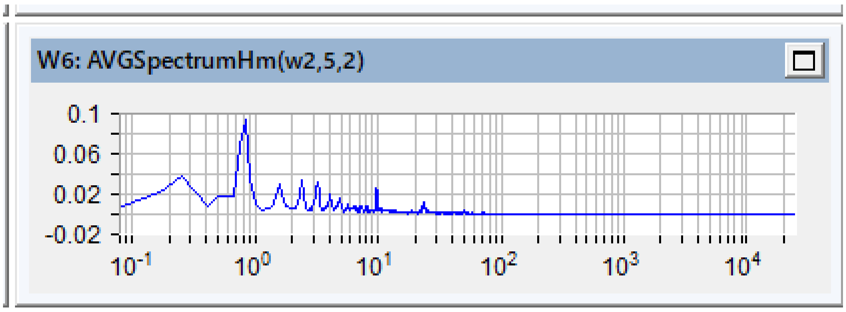
]2.2-11(1)　風力発電機から発生する騒音の周波数特性（FFT 分析結果：8m/s）

If you look closely on the left side, you will see that it says A-weighted sound pressure level [dB].

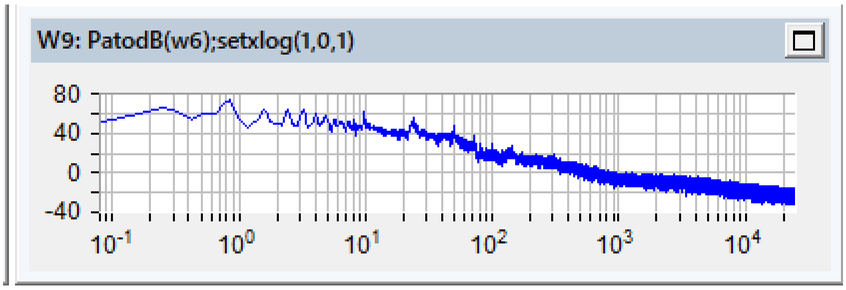
Ty4Weight



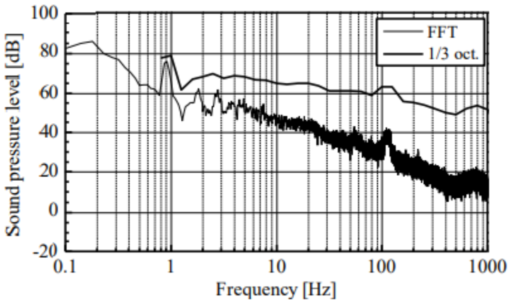
The frequency spectrum of the wind-turbine sound of W2 (averaged 5 times) is W6 (sound pressure, Pascal).



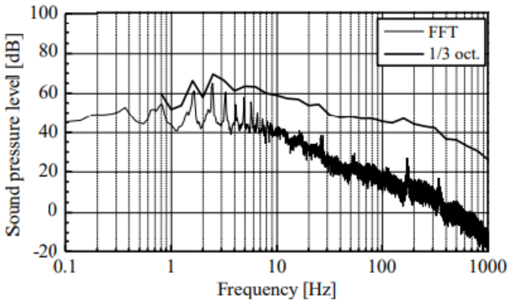
W9 is the sound pressure level (dB) converted from sound pressure (Pa).



This is called the spectrum of sound pressure.

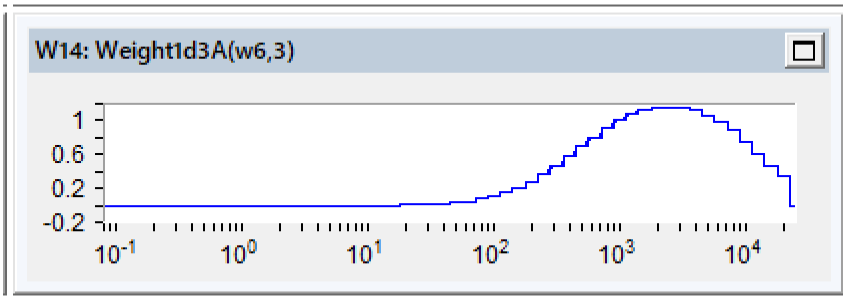


図(2)-11　図(2)-9の音圧のスペクトル



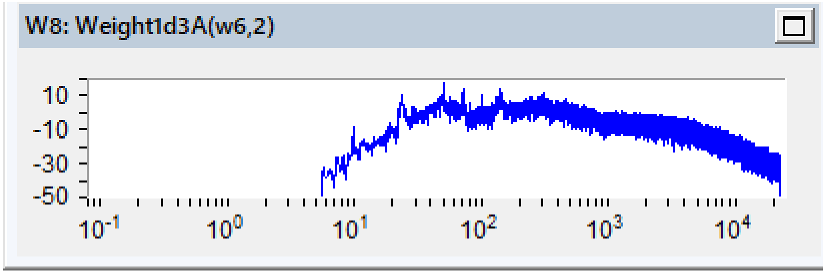
図(2)-12　図(2)-10の音圧のスペクトル

On the other hand, weighting with A-characteristics

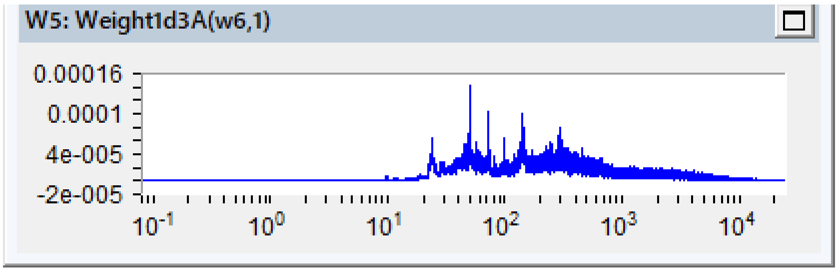


The following graph is formed.

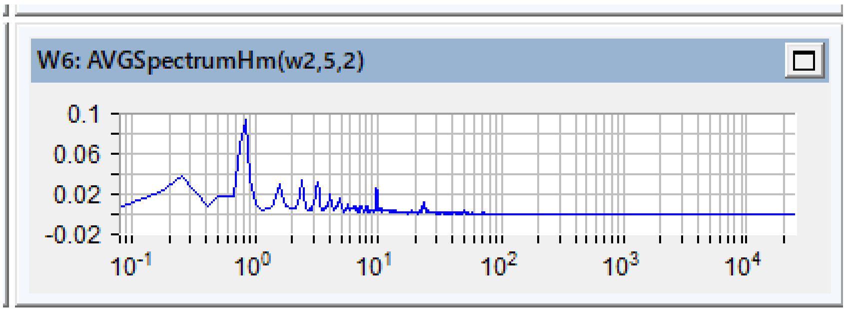
A-weighted sound pressure level [dB]



If we return this to the display in units of sound pressure (Pa), we get the following graph.



Original Graph



Compared to that, it is a completely different graph.

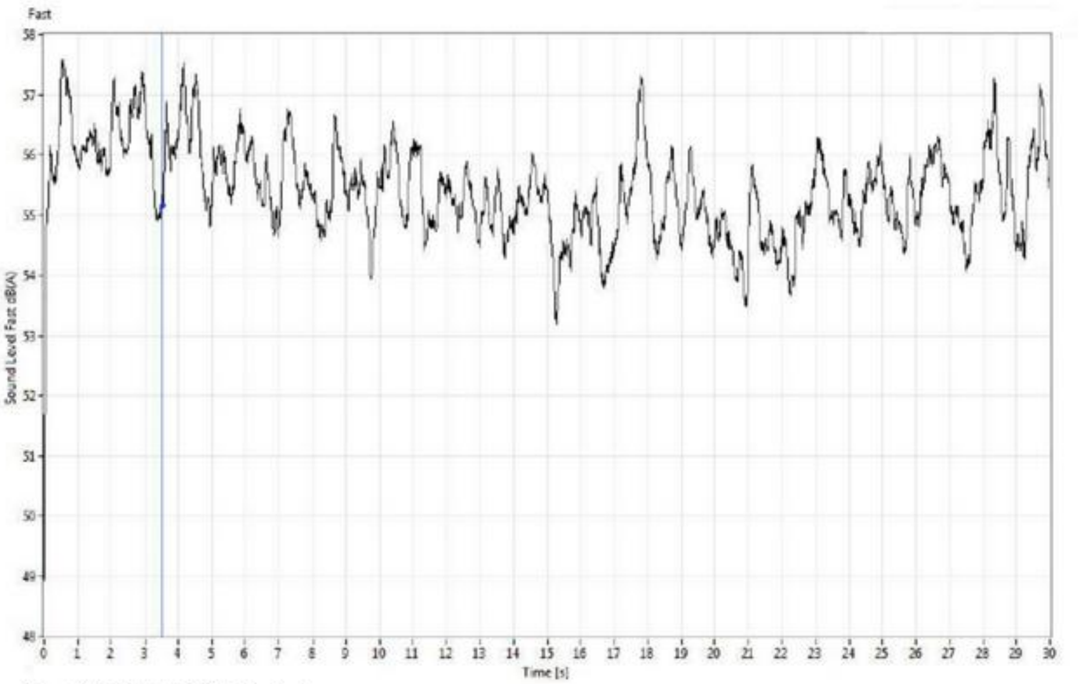
From the FFT, if we calculate the frequency spectrum, we get the original graph. The results of FFT analysis are those that use A-characteristic weighting to eliminate the infrasound part.

What is clear is that the weighting of the A characteristic excludes infrasound components.

・A characteristic sound Fluctuations in sound pressure levels

Next,

ブレードの回転に伴い約 1.5 秒ごとに音圧レベルの変動がみられ、変動幅は 1～3dB 程度となっている。



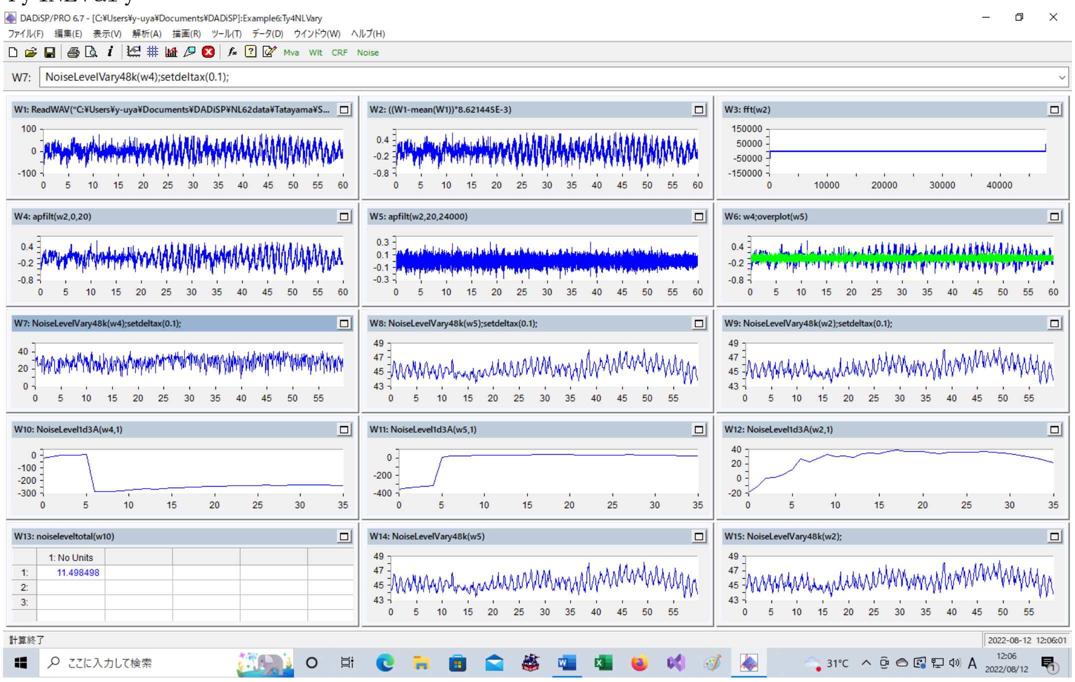
注） 調査時の風速は 8.9m/s

測定位置はロータ中心から 120m の地点

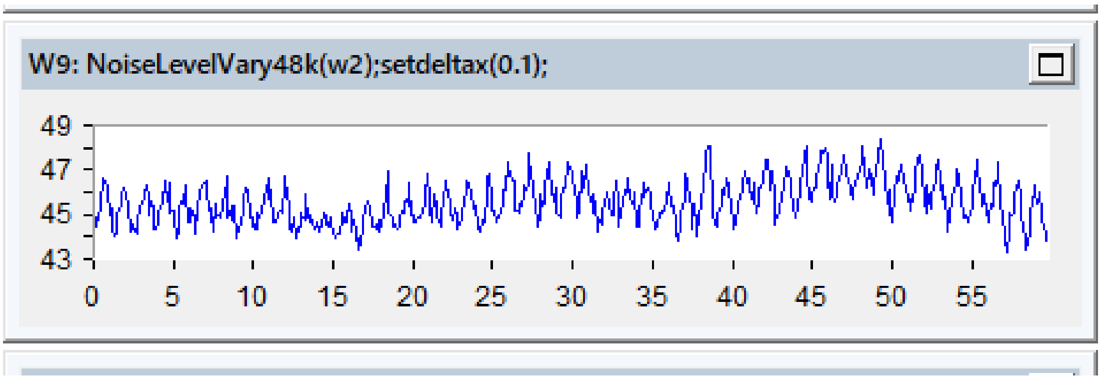
図 2.2-10　風力発電機から発生する騒音レベルの時間変動

We will consider the part of.

Ty4NLVary



The fluctuation of the sound pressure level in the A characteristic is shown in the following graph.

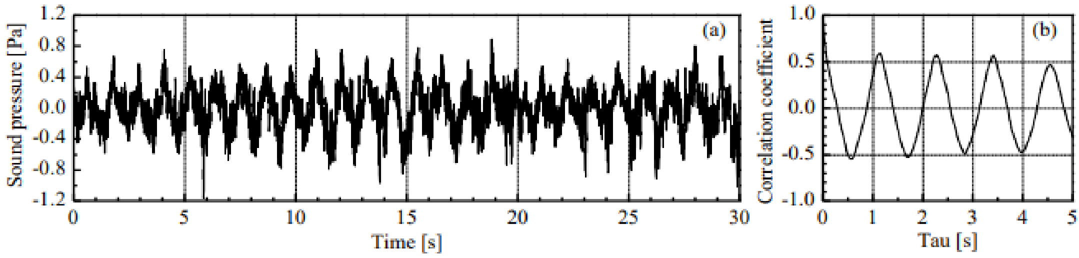


This is the result of calculating the A-weighted sound pressure level every 0.25 seconds.

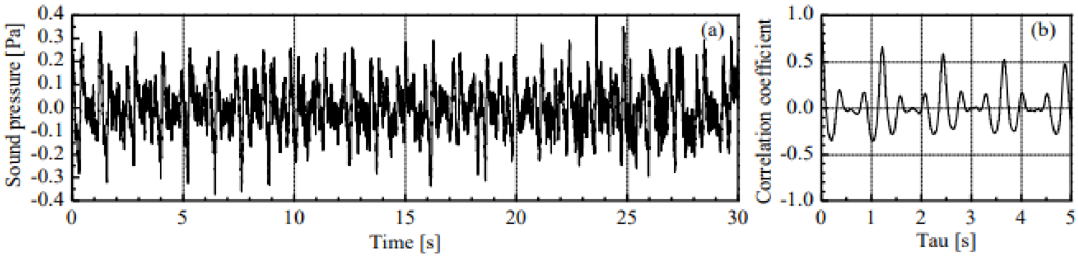
"Project Title: S2-11 Research on the Evaluation of the Effects of Wind Power Generation on Humans"

The following graph is located in the

If you compare it with the graph of autocorrelation calculated earlier and the graph of the A-weighted sound pressure level calculated every 0.25 seconds, the part on the right looks like a graph showing the fluctuation of the A-weighted sound pressure level rather than a graph of autocorrelation.



図(2)-9　1,980 kW風車の近傍における音圧とその自己相関関数



図(2)-10　2,500 kW風車7機の施設から561m離れた点における音圧とその自己相関関数

In addition

○一方で、風力発電施設から発生する20Hz以下の超低周波音については、人間の知覚閾値を下回ること、他の騒音源と比べても低周波数領域の卓越は見られず、健康影響との明らかな関連を示す知見は確認されなかった。

In the noise data observed at the wind turbine in Tateyama City,

The energy of the components below 20 Hz is large, and the energy of the components above 20 Hz is small.

In terms of road noise and factory noise

The energy of the components below 20 Hz is small, and the energy of the components above 20 Hz is large.

There is a big difference in the distribution of energy, and the energy in the low-frequency region is outstanding in wind turbine noise.

Since there are no observations of other wind-turbines or other noises, it is necessary to increase the number of observations before making a final decision.

・Swish sound

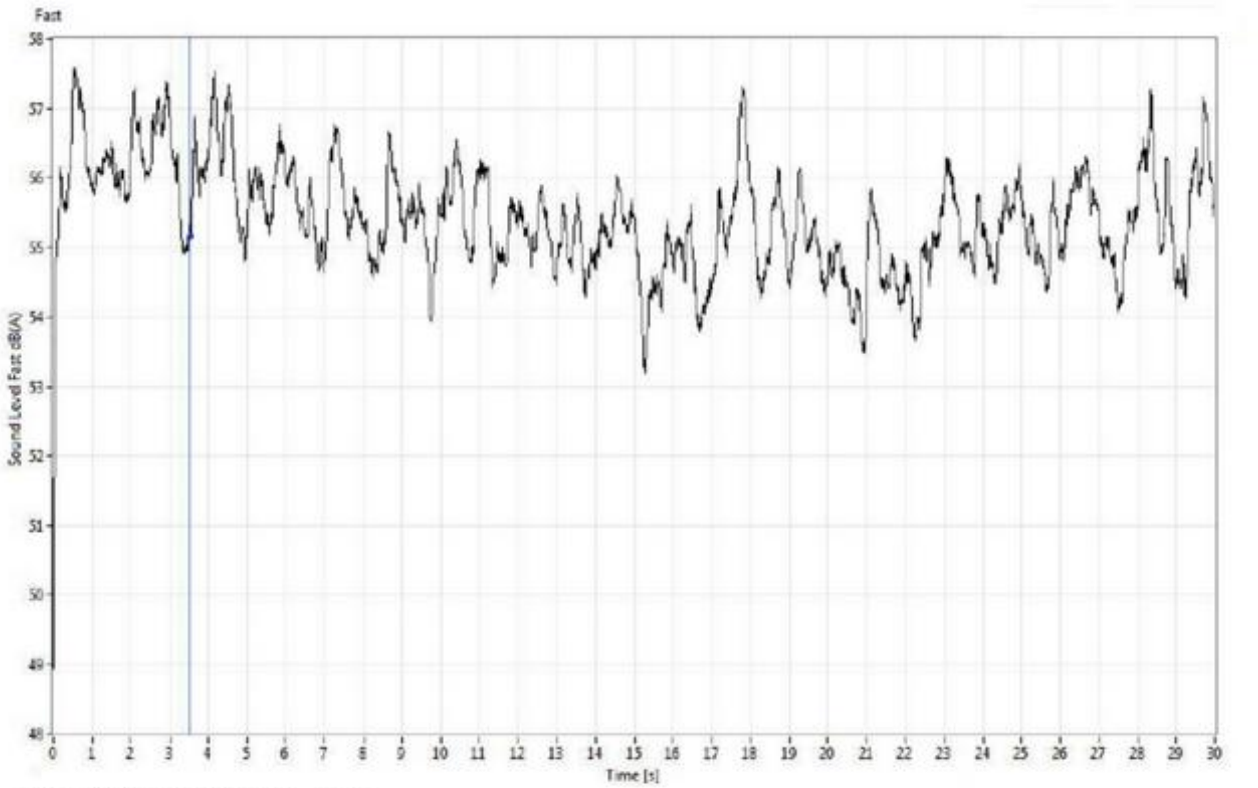
Regarding the swish sound, there was the following description.

② 機側的な音の変動（スウィッシュ音）について

風力発電機の回転に伴い発生する騒音は、周期的な変動がみられる。この音は、スウィッシュ音と呼ばれる。

風力発電機メーカーより入手した騒音の測定結果（時間変動）を、図 2.2-10 に示す。

ブレードの回転に伴い約 1.5 秒ごとに音圧レベルの変動がみられ、変動幅は 1～3dB 程度となっている。



注）調査時の風速は 8.9m/s
　　測定位置はロータ中心から 120m の地点

図 2.2-10　風力発電機から発生する騒音レベルの時間変動

The Ministry of the Environment says it is an amplitude-modulated sound.

Guidelines for Noise Generated by Wind Farms

Since wind power generation facilities are often installed in quiet areas, the level of noise generated from them may be relatively low, but it may be easy to hear in the surrounding area.

In addition, it has been suggested that amplitude modulation sounds (swish sounds) may be generated by the rotation of blades from wind power generation facilities, and pure tonic components may be generated from internal speed increasers and cooling devices in some facilities, and these sounds may increase annoyance (anoiance) and increase the risk of sleep effects.

On the other hand, extremely low frequency sound of 20 Hz or less generated by wind farms was below the human perception threshold, and compared to other noise sources, the low frequency range was not prominent, and there was no clear association with health effects.

Since the story is confusing, let's sort out the basics.

Review the concept of amplitude modulation.

Confirm that the sound pressure of wind turbine noise fluctuates with rotation, but this variation cannot be called amplitude modulation.

Therefore, the following statement is incorrect.

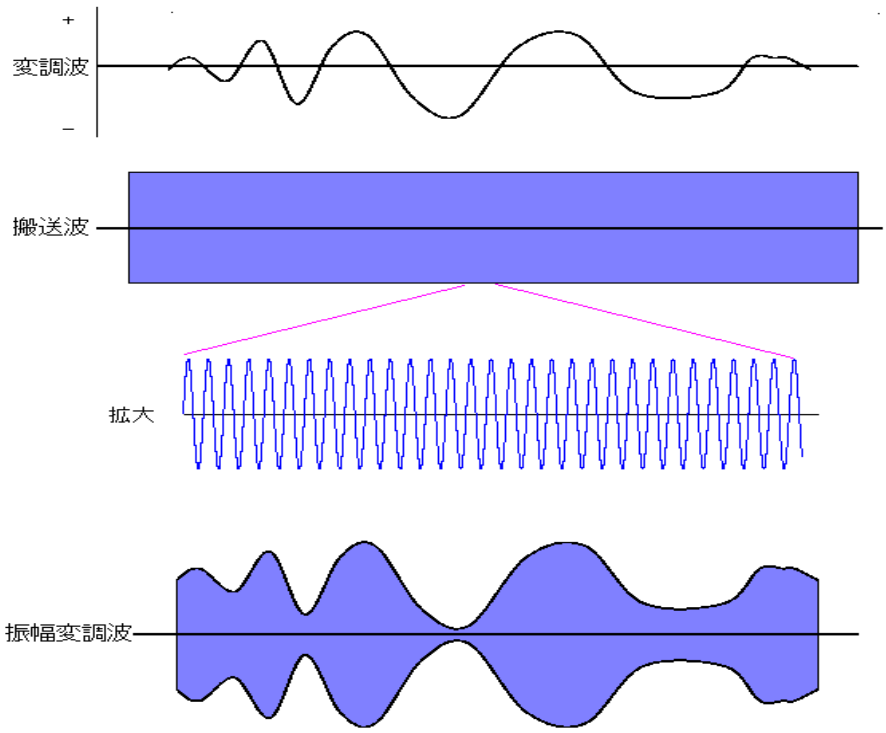
風力発電機の回転に伴い発生する騒音は、周期的な変動がみられる。この音は、スウィッシュ音と呼ばれる。

3. Check for fluctuations in sound pressure levels

ブレードの回転に伴い約 1.5 秒ごとに音圧レベルの変動がみられ、変動幅は 1～3dB 程度となっている。

About Amplitude Modulation

Amplitude modulation is a communication modulation method that transmits information mainly consisting of audio signals by changing the amplitude of radio waves and light waves. In the figure below, the modulated wave modulated by amplitude modulation is described as a function of time, with the vertical axis as a voltage value [V] and the horizontal axis as time [Sec.].



In the above figure, the frequency of the carrier wave (carrier, English: carrier wave) for transmitting it to the modulation frequency band such as an audio signal is relatively much higher than the modulation frequency band (20Hz to 20kHz) (medium wave broadcasting500-1300 kHz), a part of the waveform of the carrier wave was enlarged and expressed. In the modulated wave, the amplitude voltage value of the amplitude modulated wave is maximized when the voltage amplitude value is the maximum positive value, and conversely, the amplitude voltage value is minimized when the same modulated wave is negative. See the Theory section for details. Here, the modulated wave may be read as a signal wave (the original signal (voice, music, etc.) to be transmitted).

It is a concept that there is a wave with a high frequency such as a carrier wave, and its amplitude is modulated by a wave having a relatively low frequency, and if there is no carrier part whose amplitude is modulated, it becomes a meaningless concept.

In the case of wind-turbine noise, how many hertz of waves is the amplitude modulated? In the first place, there is no wave to be modulated.

If it means a wave with a fluctuating amplitude, it should be called an amplitude fluctuation wave, and we should not use the term amplitude modulated wave, which is already an established concept.

When I wrote low-frequency sound waves, high-frequency sounds, $Asin(\omega t)Bsin(200\omega t)$ Suppose that 0, B>0 and A and B are approximately equal.)

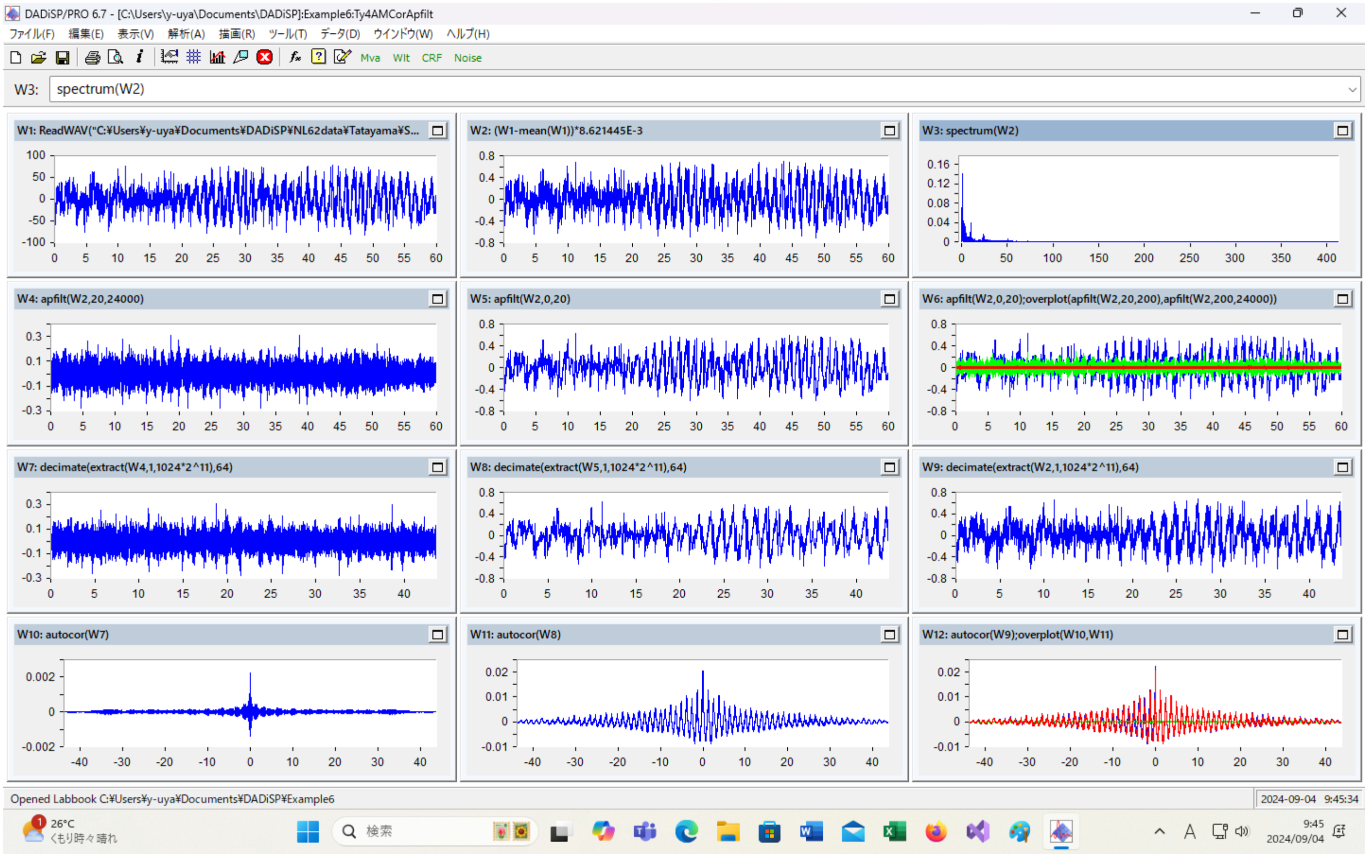
Amplitude modulation should vary in amplitude B, such as . $(B + 0.1Asin(\omega t)) * sin(200\omega t)$

In the case of the observed wind-turbine sound, it is in the form of, and on top of the strong infinitesimal sound, a state in which a weak high-frequency component acts and a small wave is standing. $Asin(\omega t) + 00.1Bsin(200\omega t)$

We will consider this using the data of wind-turbine noise in Tateyama.

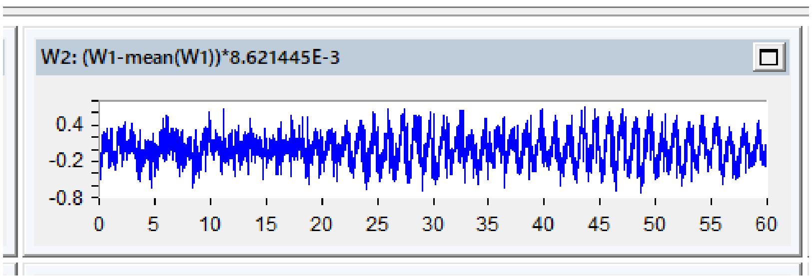
The observed sound is variable in amplitude. However, it cannot be said that there is something that corresponds to the carrier wave, and its amplitude is changing.

Ty4AMCorApfilt



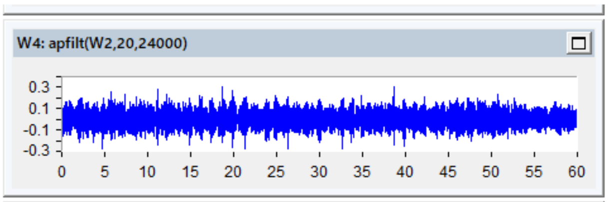
If you look at the

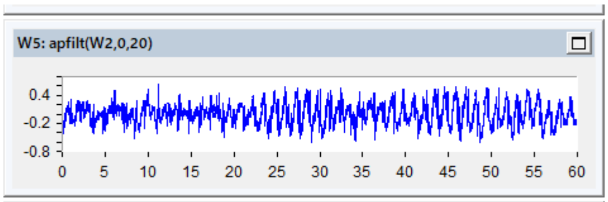
The observed sound is



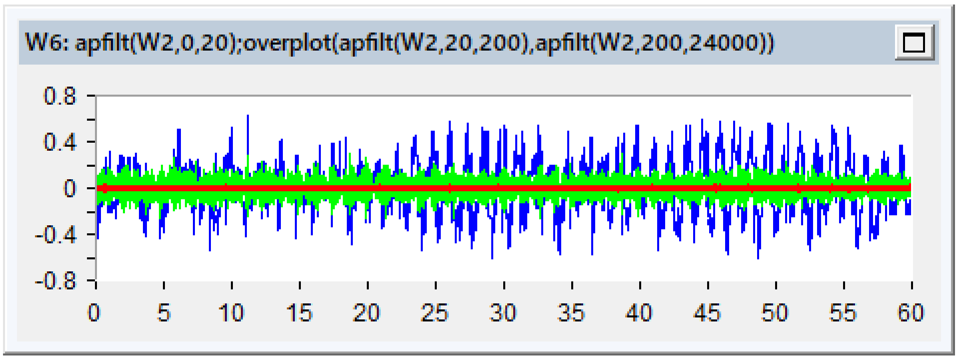
です。

If we break this down into components above 20 Hz and components below 20 Hz, we get the figure below.



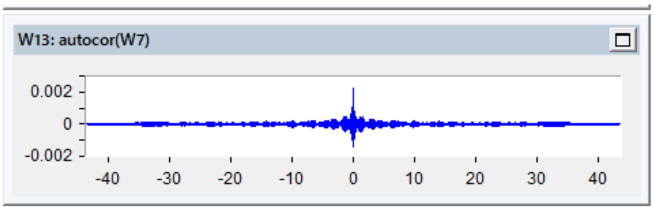


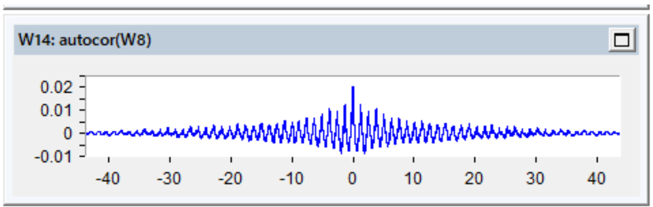
Furthermore, if you superimpose dark blue as a component of 20 Hz or less, yellow-green as a component of 20 Hz to 200 Hz, and red as a component of 200 Hz or more, you will get the following figure.



This means that the sound below 20 Hz determines the overall fluctuation. Sounds above 20 Hz serve to attach small thorns to the fluctuations. It shows:

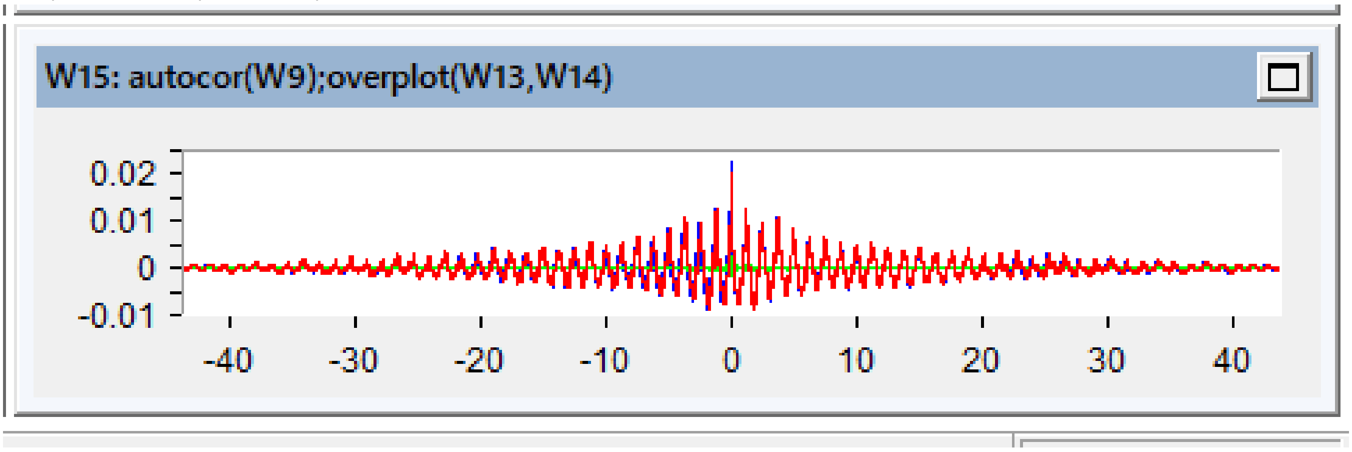
Calculating the autocorrelation of the components in the audible range and the rest of the spectrum,





It can be seen that the components above 20 Hz do not have the periodicity that was the eye. It can be seen that the components below 20 Hz have a considerable periodicity.

If you overlay this, you can see that



Dark blue is the autocorrelation of the observed sound, red is the autocorrelation of sounds below 20 Hz, and green is the autocorrelation of sounds of 20 Hz or more.

It can be seen that the observed data itself and the sound below 20 Hz show strong periodicity, and the sound above 20 Hz does not have a clear periodicity. We can also see that the periodicity as a whole is determined by the periodicity of the sound below 20 Hz.

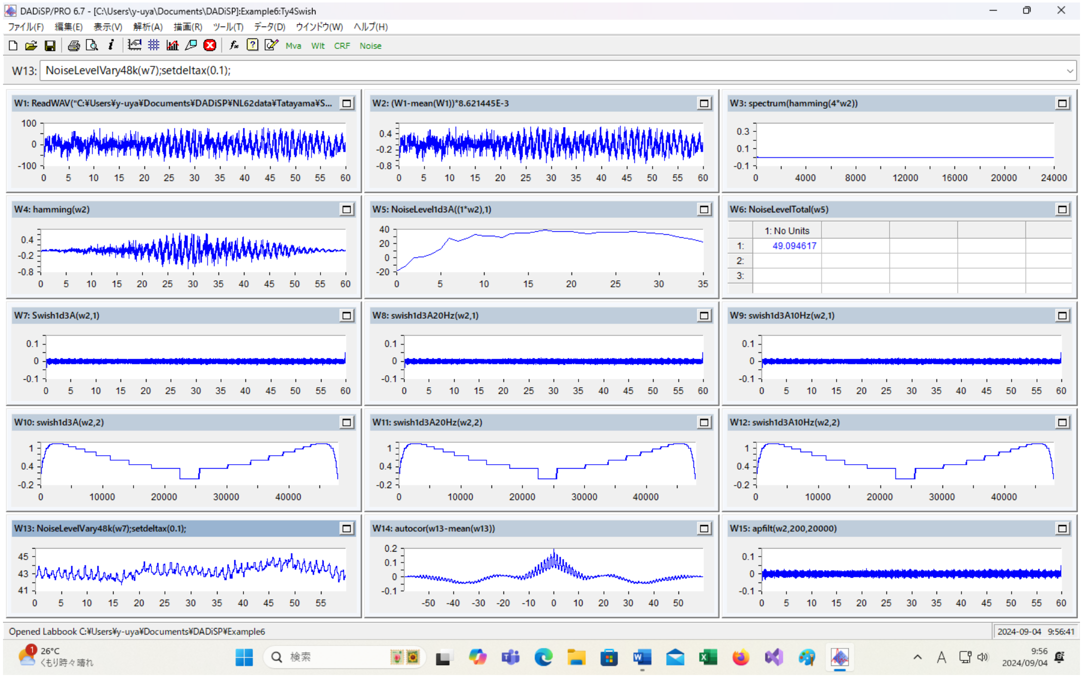
風力発電機の回転に伴い発生する騒音は、周期的な変動がみられる。この音は、スウィッシュ音と呼ばれる。

The periodic fluctuations that are immediately noticeable can be said to be the effect of sounds below 20 Hz with strong energy.

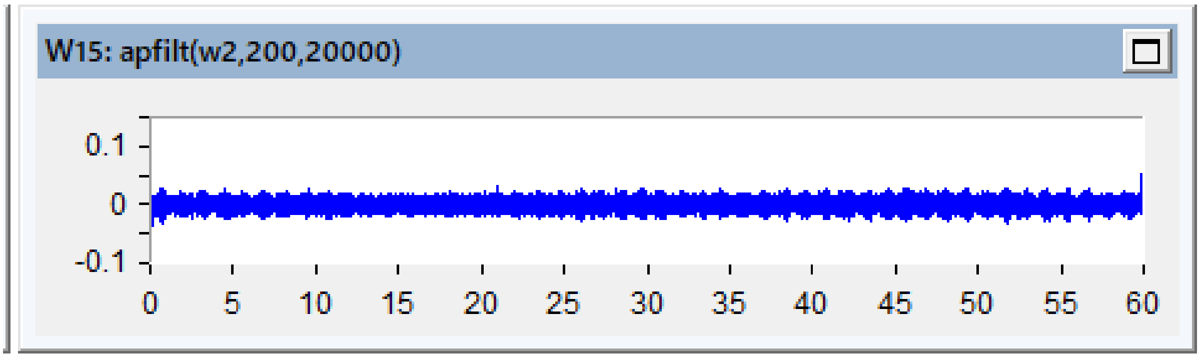
This phenomenon cannot be expressed by the word "swish" for amplitude modulation.

About the phenomenon that can be called amplitude modulation.

Ty4Swish

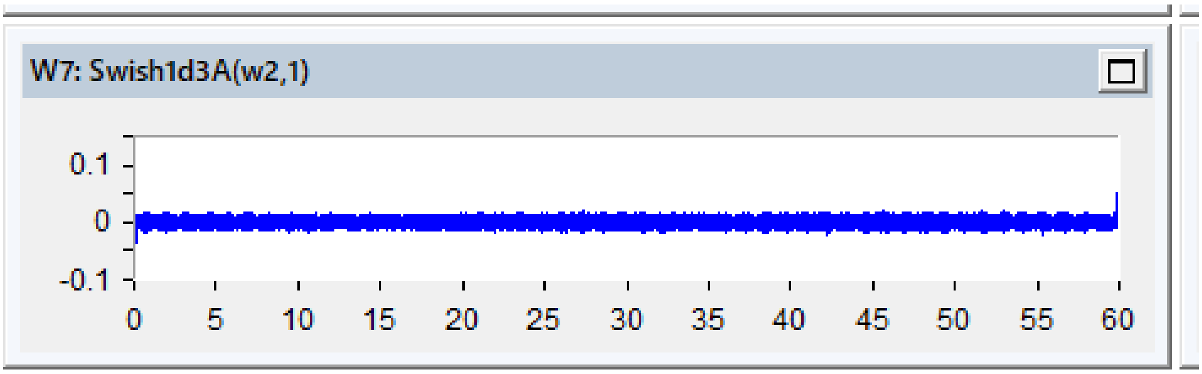


If you take out the sound from 200 Hz to 20 kHz, you will get the following figure.



This phenomenon can be called amplitude modulation.

Furthermore, in consideration of the A characteristic, if the part of the audible range is taken out,



You will get the diagram above. In this sense, it can be said that the sound in the audible range stimulates human hearing as amplitude-modulated sound.

3.5 G-weighted sound pressure level

Regarding G characteristics, a **manual on how to measure low-frequency sound Heisei 12 October According** to the materials of the Air Conservation Bureau of the Environment Agency,

1～20 Hz の傾斜は，超低周波音領域における感覚閾値の実験結果に基づいている。

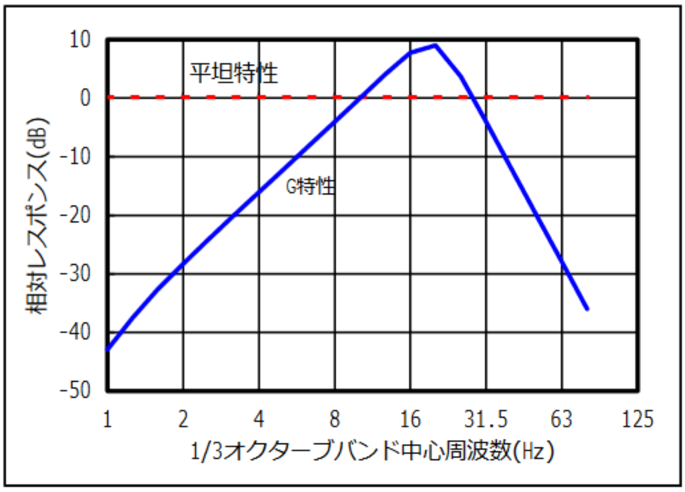


図-1.1　低周波音の周波数補正特性

表-1.1　基準周波数レスポンス及び許容差

中心周波数(Hz)	平坦特性		G 特性	
	基準レスポンス(dB)	許容差(dB)	基準レスポンス(dB)	許容差(dB)
1	0	±3	– 43	±3
1.25	0	±3	– 37.5	±3
1.6	0	±3	– 32.5	±3
2	0	±2	– 28.3	±2
2.5	0	±2	– 24.1	±2
3.15	0	±1.5	– 20	±1.5
4	0	±1	– 16	±1
5	0	±1	– 12	±1
6.3	0	±1	– 8	±1
8	0	±1	– 4	±1
10	0	±1	– 0	±1
12.5	0	±1	4	±1
16	0	±1	7.7	±1
20	0	±1	9	±1
25	0	±1	3.7	±1
31.5	0	±1	– 4	±1
40	0	±1	– 12	±1
50	0	±1	– 20	±1
63	0	±1	– 28	±1
80	0	±1.5	– 36	±1.5

It has become,

The center frequency ranges from 1 Hz to 80 Hz.

（function Weight1d3G(ww,h,w) と NoiseLevel1d3G(ww,h,w) This standard）

ISO7196:1995 uses center frequencies ranging from 0.25 to 315 Hz.

The weights in the G-characteristic in the ISO7196 are as follows:

	1	2	3	4	5	6	7	8	9	10	11
中心周波数Hz	0.25	0.315	0.4	0.5	0.63	0.8	1	1.25	1.6	2	2.5
G特性での重み	-88.00	-80.00	-72.10	-64.30	-56.60	-49.50	-43.00	-37.50	-32.60	-28.30	-24.10

	12	13	14	15	16	17	18	19	20	21	22
中心周波数Hz	3.15	4	5	6.3	8	10	12.5	16	20	25	31.5
G特性での重み	-20.00	-16.00	-12.00	-8.00	-4.00	0.00	4.00	7.70	9.00	3.70	-4.00

	23	24	25	26	27	28	29	30	31	32
中心周波数Hz	40	50	63	80	100	125	160	200	250	315
G特性での重み	-12.00	-20.00	-28.00	-36.00	-44.00	-52.00	-60.00	-68.00	-76.00	-84.00

(It is this standard that is 7196, as in the functions Weight1d3G7196(ww,w) and NoiseLevel1d3G7196(ww,w).) ）

Learn more about ISO 7196:1995

Acoustics — Frequency-weighting characteristic for infrasound measurements （Japan Standards Association）

Please confirm.

About Center Frequency

The nominal frequency is the center frequency of each 1/3 octave band, expressed as a sharp frequency.

The exact frequency is the exact center frequency value of each band obtained by Equation (1) with the band number n as an integer of 10~33.

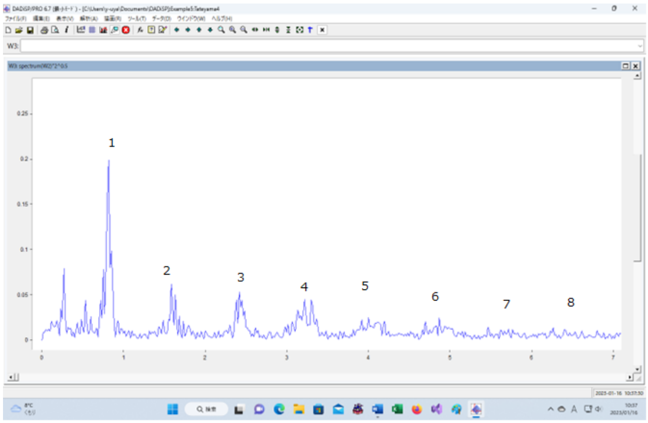
$$f = 1000 \times 10^{0.1 \times (n-30)} \quad [\mathrm{Hz}] \qquad \text{......} \quad (1)$$

(n=10,f=10, n=13,f= 19.95262315, , n=33,f= 1995.262315)

	1/3オクターブバンド中心周波数と帯域幅（ISO7196）0.25～315Hz					
x	x/3	2^(x/3)	中心周波数 1000*2^(x/3)	f 1	f 2	帯域幅
36	-12	0.000244	0.244	0.218	0.274	0.057
35	-11.6667	0.000308	0.308	0.274	0.345	0.071
34	-11.3333	0.000388	0.388	0.345	0.435	0.090
33	-11	0.000488	0.488	0.435	0.548	0.113
32	-10.6667	0.000615	0.615	0.548	0.691	0.142
31	-10.3333	0.000775	0.775	0.691	0.870	0.179
30	-10	0.000977	0.977	0.870	1.096	0.226
29	-9.66667	0.00123	1.230	1.096	1.381	0.285
28	-9.33333	0.00155	1.550	1.381	1.740	0.359

The nominal frequencies in ISO7196 are 0.25, 0.315, and 0.4 Hz. The bandwidths of the center frequencies of 0.25 Hz and 0.315 Hz are 0.057 Hz and 0.071 Hz. If you calculate the data for 60 seconds and set the frequency resolution to 0.0166 Hz, you can also calculate according to the ISO7196.

What I want is a graph and table like this:



Frequency at peak[Hz]	Rate(1)	Rate(2)	Sound pressure[Pa]
0.2667	1.0000		0.0560
0.5333	2.0000		0.0309
0.8167	3.0625	1.0000	0.1405
1.5833	5.9375	1.9388	0.0436
2.4167	9.0625	2.9592	0.0242
3.2167	12.0625	3.9388	0.0317
4.0000	15.0000	4.8980	0.0177
4.8667	18.2500	5.9592	0.0173
5.4667	20.5000	6.6939	0.0101
6.2667	23.5000	7.6735	0.0098

If there are 10 data between the peak values, a resolution of (0.5333-0.2667)/10 = 0.0266 Hz is required, and if there are 20 numbers in between, a resolution of 0.0133 Hz is required.

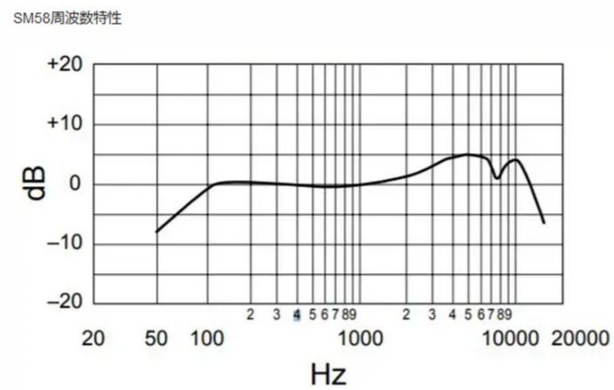
The maximum sound pressure of a large wind turbine is around 0.5 Hz. The leftmost peak is 0.5/3 = 0.1667 Hz, and the second peak from the left is 0.3333 Hz. To get a smooth graph, you need to take 10 or more points during this time. Sound pressure in 0.01667 Hz increments is required. This means that a frequency resolution of about 0.01667 Hz is required.

In ISO7196, the center frequencies are 0.25 Hz and 0.3 Hz. Since (0.3-0.25)/10=0.005, if possible, if the frequency resolution is set to about 0.0083Hz, the G-weighted sound pressure level can be calculated according to the ISO7196.

The trouble is that the revolution speed of the wing has decreased due to the increase in size, so the fundamental frequency has become 0.5 Hz or 0.8 Hz.

The microphone used in karaoke cannot accurately grasp the given sound pressure level for sounds below 100 Hz. (Left graph below)

Special microphones for infrasound can accurately measure up to 1 Hz or even 0.5 Hz. If you learn about sound pressure compensation later, you can measure up to around 0.8 Hz even with the NL-62. (Right graph below)



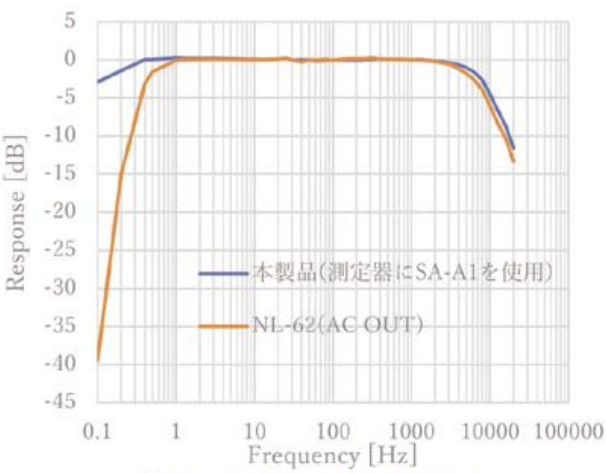


図2　本製品とNL-62 の周波数特性

UC-59L and SA-A1 (about 1.2 million yen)

周波数範囲	DC～20 kHzまたは0.25 Hz～20 kHz

Others:

番号	種類	測定範囲
NL-62A	精密騒音計	1Hz～20000Hz
NL-52A	精密騒音計	10Hz～20000Hz
NL-42A	普通騒音計	20Hz～8000Hz
NL-27	普通騒音計	20Hz～8000Hz
NA-28	精密騒音計	12.5Hz～20000Hz

As for the measurement range, the lowest one is from 0.25 Hz for the SA-A1.

The NL-62, NL-62A, NL-63 and SA-A1 use the same microphone. However, there is a difference in the measurement range.

To determine the frequency, it is not possible to simply measure the sound pressure with a microphone. FFT calculations are required.

60 seconds of data is required to drill down into the details.

Trouble happens. Assuming it takes 60 seconds to measure and 6 seconds to calculate FFT, the screen will remain stopped for 66 seconds after the switch is turned on. Furthermore, at a sampling rate of 48 kHz per second, 48000 * 60 = 2880000 pieces of data will be stored in memory. FFT is a fast algorithm, but it cannot perform high-speed calculations on the CPU of a precision sound level meter. Therefore, if you decide to calculate with 10 seconds of measurement data, the number of data will be reduced to 1/6, and the amount of memory and calculation will be reduced.

If FFT is calculated for 48000 * 60 pieces of data, the same number of numerical values can be obtained, and if the frequency increment width is hHz, h * 48000 * 60 = 48000, so h = 0.01667Hz

The frequency spectrum ranges from 0 Hz to 24000 Hz, and the frequency resolution is h = 0.01667 Hz.
It will be calculated from 0 Hz to 24000 Hz in increments of 0.01667 Hz.

If FFT is calculated for 48000 * 10 pieces of data, the same number of numerical values can be obtained, and if the frequency step width is hHz, h * 48000 * 10 = 48000, so h = 0.1Hz

The frequency spectrum ranges from 0 Hz to 24000 Hz, and the frequency resolution is h = 0.1 Hz.
It will be calculated from 0 Hz to 24000 Hz in increments of 0.1 Hz.

Let's say you want to use this result to perform a 1/3 octave analysis.

The lower row is the center frequency, and the upper row is the sound pressure level.

W15: transpose(w12)

	1: No Units	2: No Units	3: No Units	4: No Units	5: No Units	6: No Units	7: No Units
1:	54.727250	62.381626	54.976763	56.733648	58.610999	77.287140	64.371465
2:	0.250000	0.315000	0.400000	0.500000	0.630000	0.800000	1.000000
3:							

(5)　G特性音圧レベル

ISO 7196 に定められた周波数補正特性 G 特性で重み付けられた音圧レベル。基準音圧は 2×10^{-5} Pa，単位は dB。

$$L_G = 10\log_{10}\frac{p_G^2}{p_0^2}$$

L_p：G 特性音圧レベル（dB）

p_G：G 特性音圧の実効値（Pa）

p_0：基準音圧　2×10^{-5} (Pa)

For infrasound sounds subject to G characteristics, the bandpass filter characteristics are

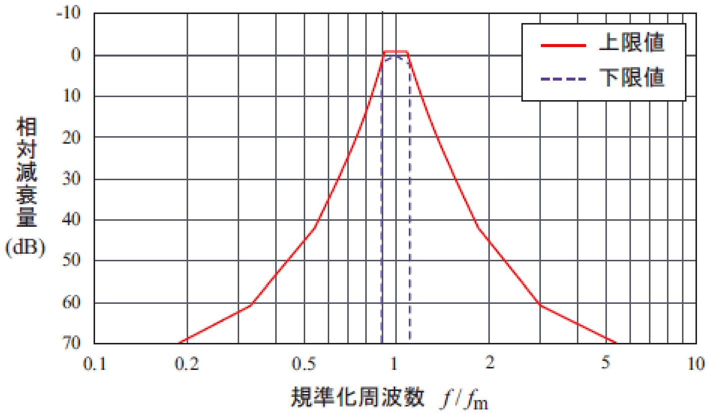


図 11-5　1/3 オクターブバンドフィルタ クラス 1 の相対減衰量の限界値

It has become.

According to the calculation example with A characteristics, the calculation procedure is as follows:

1 Calculate the sound pressure (in Pascals) for each waveband.

2 Compare with the reference sound pressure and calculate the sound pressure level (in dB) in that frequency band.

3 Each frequency band is weighted by G-characteristics.

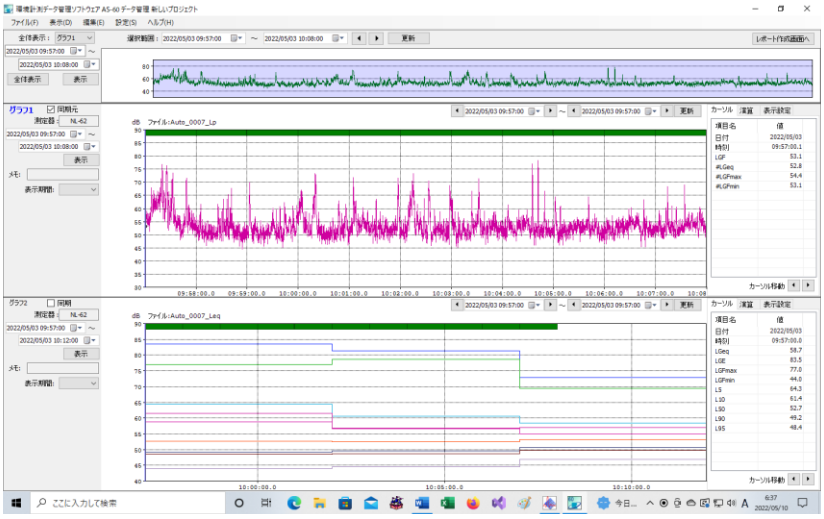
4 Based on the weighted values, calculate the overall energy and obtain the overall sound pressure level (in dB).

It will be,

Open the actual data (Auto_0007.mh from the AS-60. Let's try to calculate with (The data is from places where there are no wind-turbines.) This data is a WAV file in DADISP─NL62data─Auto_007─SOUND.

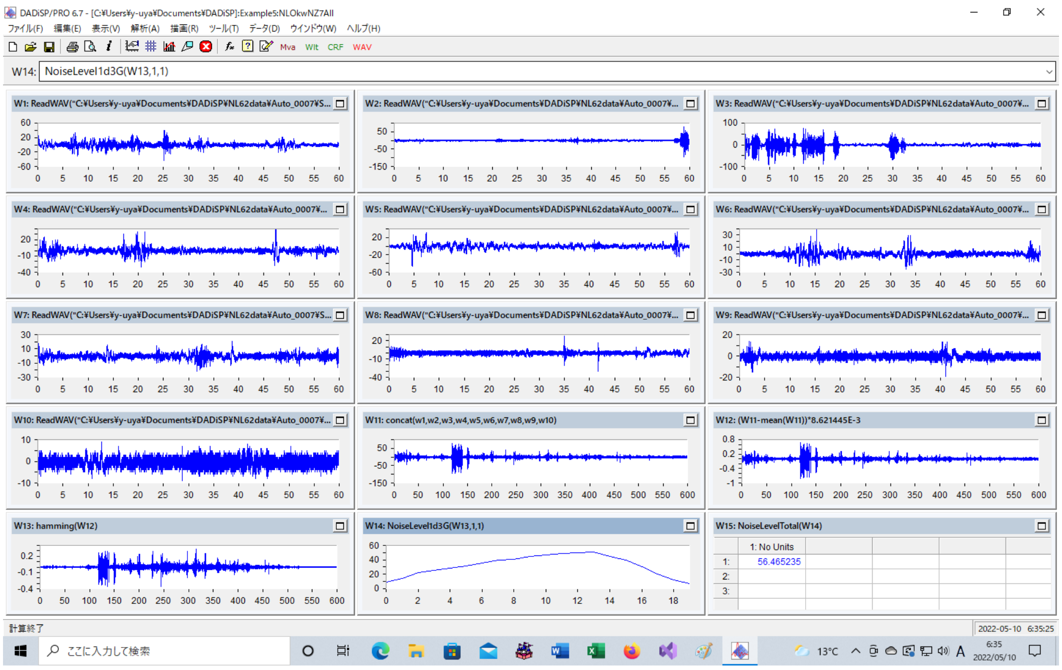
(There is a difference of about 2 dB from Lion's software, but the cause is unknown because the calculation method of Lion's software is not disclosed.) ）

For AS-60, LGeq=58.7



If you calculate the same data in DADISP (Worksheet NLOkwNZ7All)

This is a numeric import of WAV files in NLOkwNZ7All (DADISP—NL62data—Auto_007—SOUND. I deleted it because the file size is too large. ）



NoiseLevel1d3G(W13,1,1) And、 56.465235

The center frequency ranges from 1 Hz to 80 Hz.

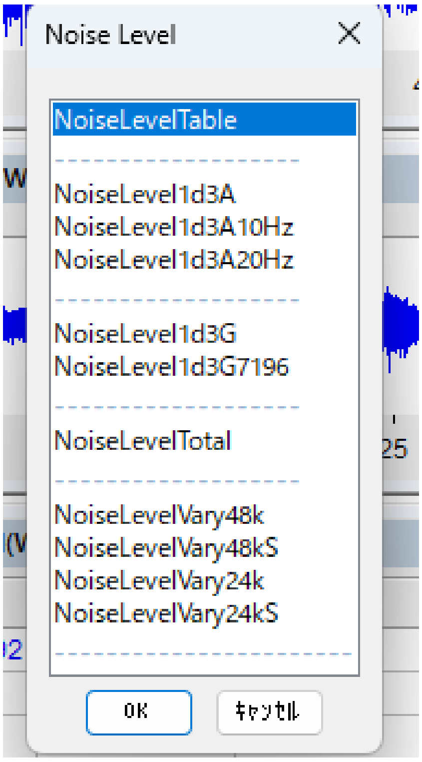
（function Weight1d3G(ww,h,w) and NoiseLevel1d3G(ww,h,w) This standard

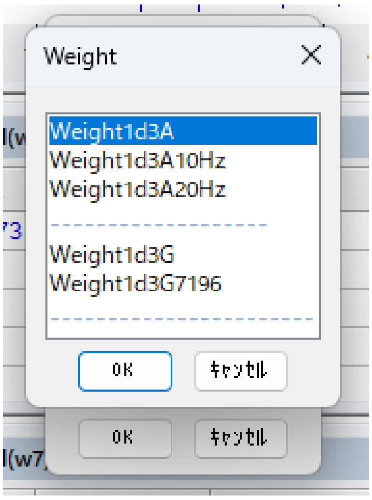
ISO7196:1995 uses center frequencies ranging from 0.25 to 315 Hz.

(It is this standard that is 7196, as in the functions Weight1d3G7196(ww,w) and NoiseLevel1d3G7196(ww,w).) ）

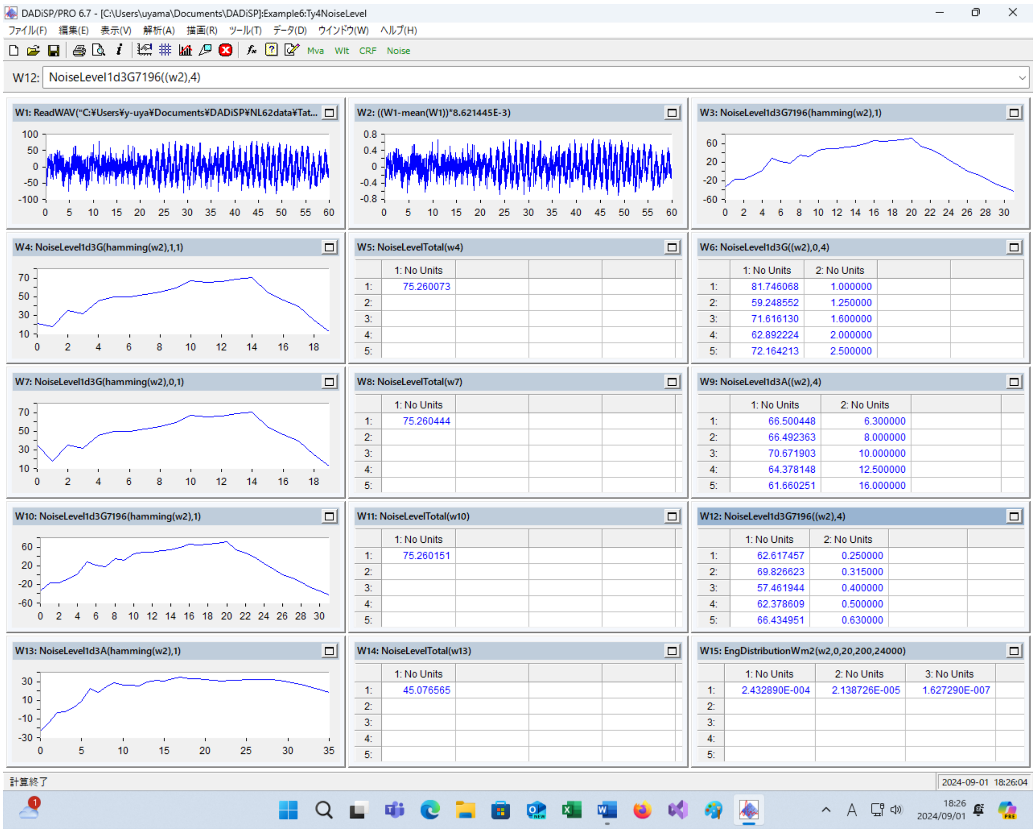
Center frequency in ISO7196

	1/3オクターブバンド中心周波数と帯域幅（ISO7196）0.25～315Hz						
x	x/3	2^(x/3)	厳密中心周波数 1000*2^(x/3)	f 1	f 2	帯域幅	公称中心周波数
36	-12	0.000244	0.244	0.218	0.274	0.057	0.250
35	-11.6667	0.000308	0.308	0.274	0.345	0.071	0.315
34	-11.3333	0.000388	0.388	0.345	0.435	0.090	0.400
33	-11	0.000488	0.488	0.435	0.548	0.113	0.500
32	-10.6667	0.000615	0.615	0.548	0.691	0.142	0.630
31	-10.3333	0.000775	0.775	0.691	0.870	0.179	0.800
30	-10	0.000977	0.977	0.870	1.096	0.226	1.000
29	-9.66667	0.00123	1.230	1.096	1.381	0.285	1.250
28	-9.33333	0.00155	1.550	1.381	1.740	0.359	1.600
27	-9	0.001953	1.953	1.740	2.192	0.452	2.000
26	-8.66667	0.002461	2.461	2.192	2.762	0.570	2.500
25	-8.33333	0.0031	3.100	2.762	3.480	0.718	3.150
24	-8	0.003906	3.906	3.480	4.385	0.905	4.000
23	-7.66667	0.004922	4.922	4.385	5.524	1.140	5.000
22	-7.33333	0.006201	6.201	5.524	6.960	1.436	6.300
21	-7	0.007813	7.813	6.960	8.769	1.809	8.000
20	-6.66667	0.009843	9.843	8.769	11.049	2.279	10.000
19	-6.33333	0.012402	12.402	11.049	13.920	2.872	12.500
18	-6	0.015625	15.625	13.920	17.538	3.618	16.000
17	-5.66667	0.019686	19.686	17.538	22.097	4.559	20.000
16	-5.33333	0.024803	24.803	22.097	27.841	5.743	25.000
15	-5	0.03125	31.250	27.841	35.077	7.236	31.500
14	-4.66667	0.039373	39.373	35.077	44.194	9.117	40.000
13	-4.33333	0.049606	49.606	44.194	55.681	11.487	50.000
12	-4	0.0625	62.500	55.681	70.154	14.473	63.000
11	-3.66667	0.078745	78.745	70.154	88.388	18.234	80.000
10	-3.33333	0.099213	99.213	88.388	111.362	22.974	100.000
9	-3	0.125	125.000	111.362	140.308	28.945	125.000
8	-2.66667	0.15749	157.490	140.308	176.777	36.469	160.000
7	-2.33333	0.198425	198.425	176.777	222.725	45.948	200.000
6	-2	0.25	250.000	222.725	280.616	57.891	250.000
5	-1.66667	0.31498	314.980	280.616	353.553	72.938	315.000





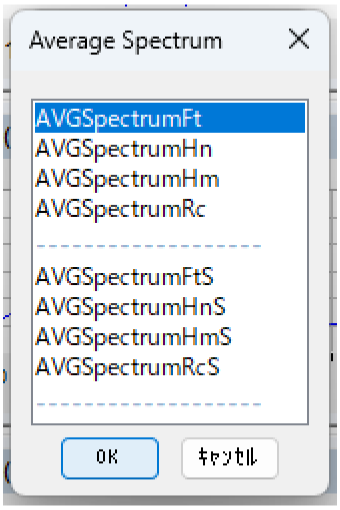
Ty4NoiseLevel



W5 : NoiseLevelTotal(NoiseLevel1d3G(hamming(w2),1,1))

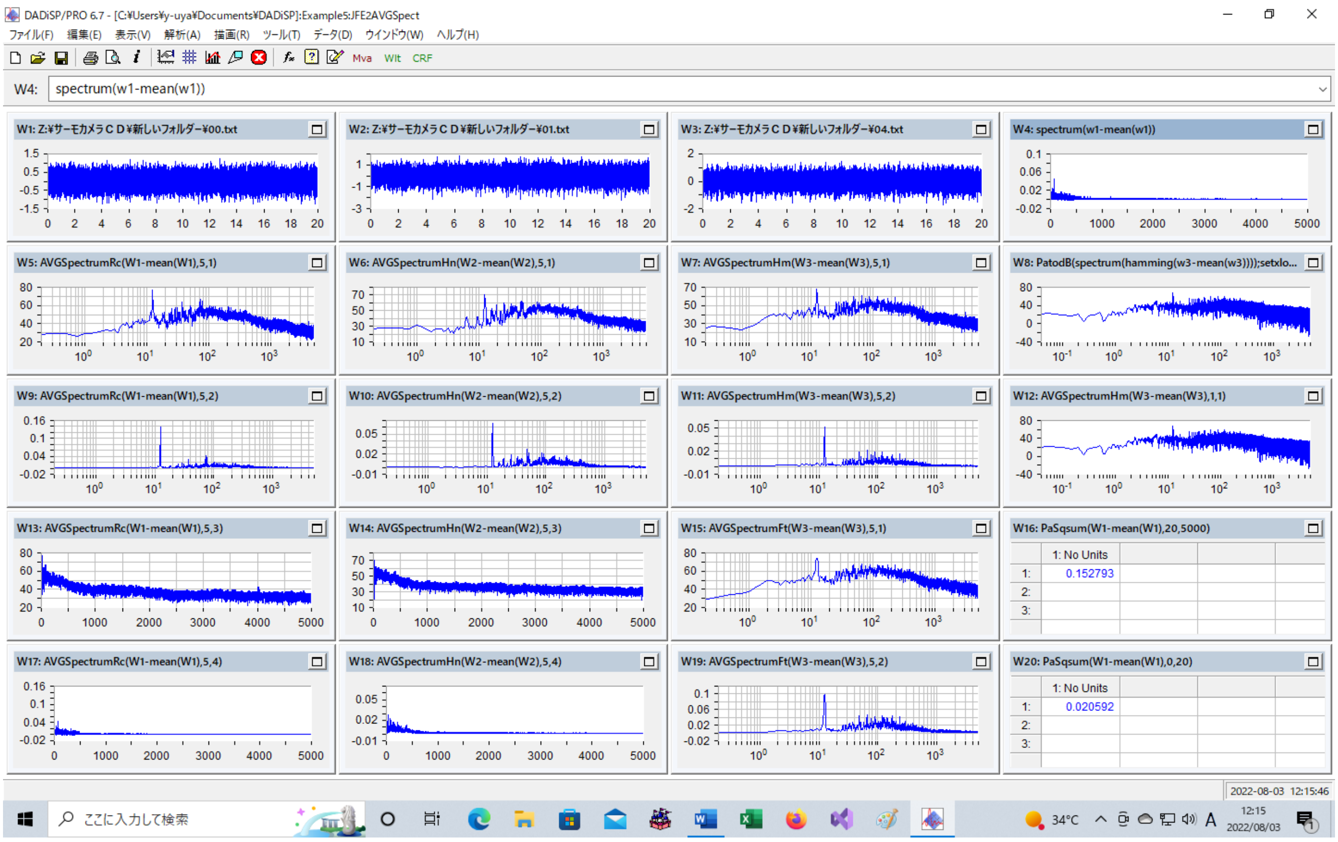
will be the same number.

- Average frequency spectrum

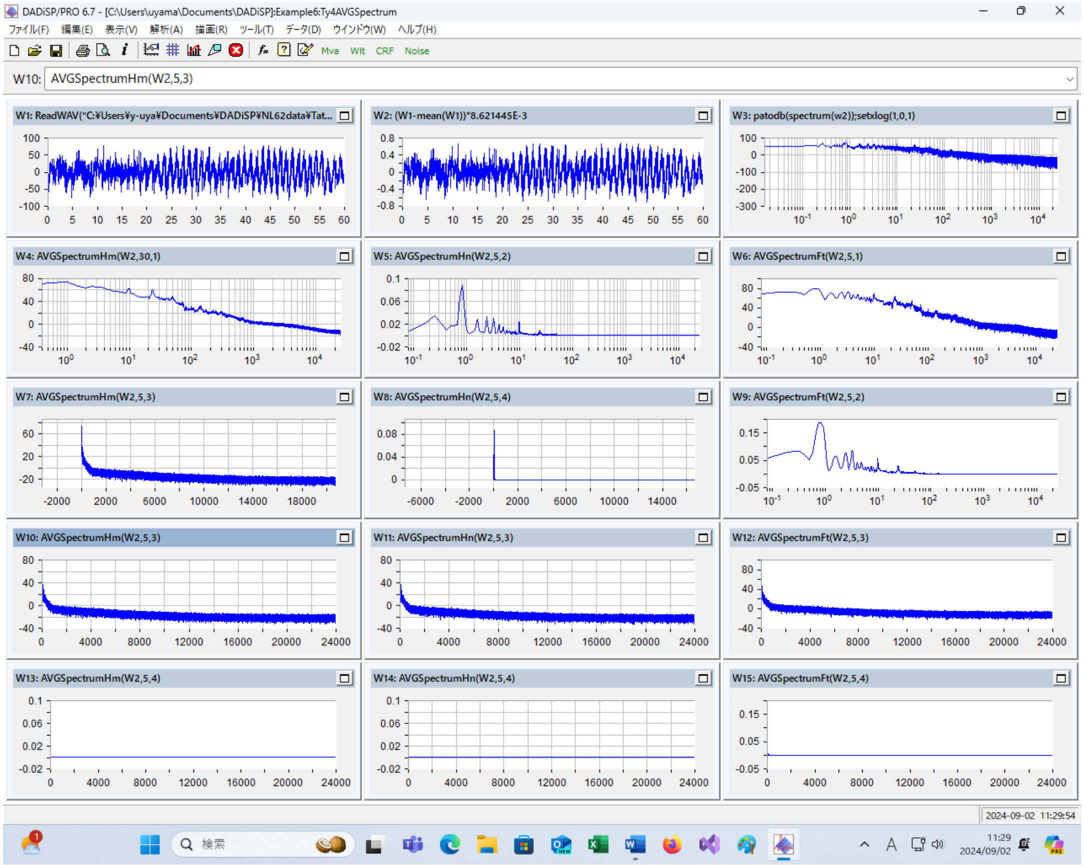


You can change the window function to calculate the averaged frequency spectrum.

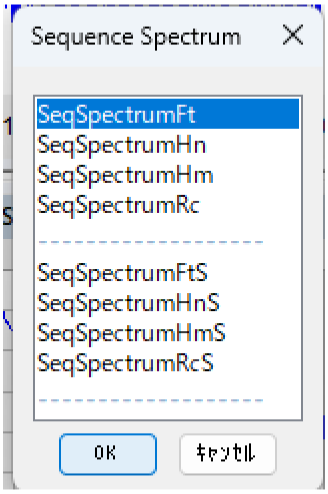
JFE2AVGSpect



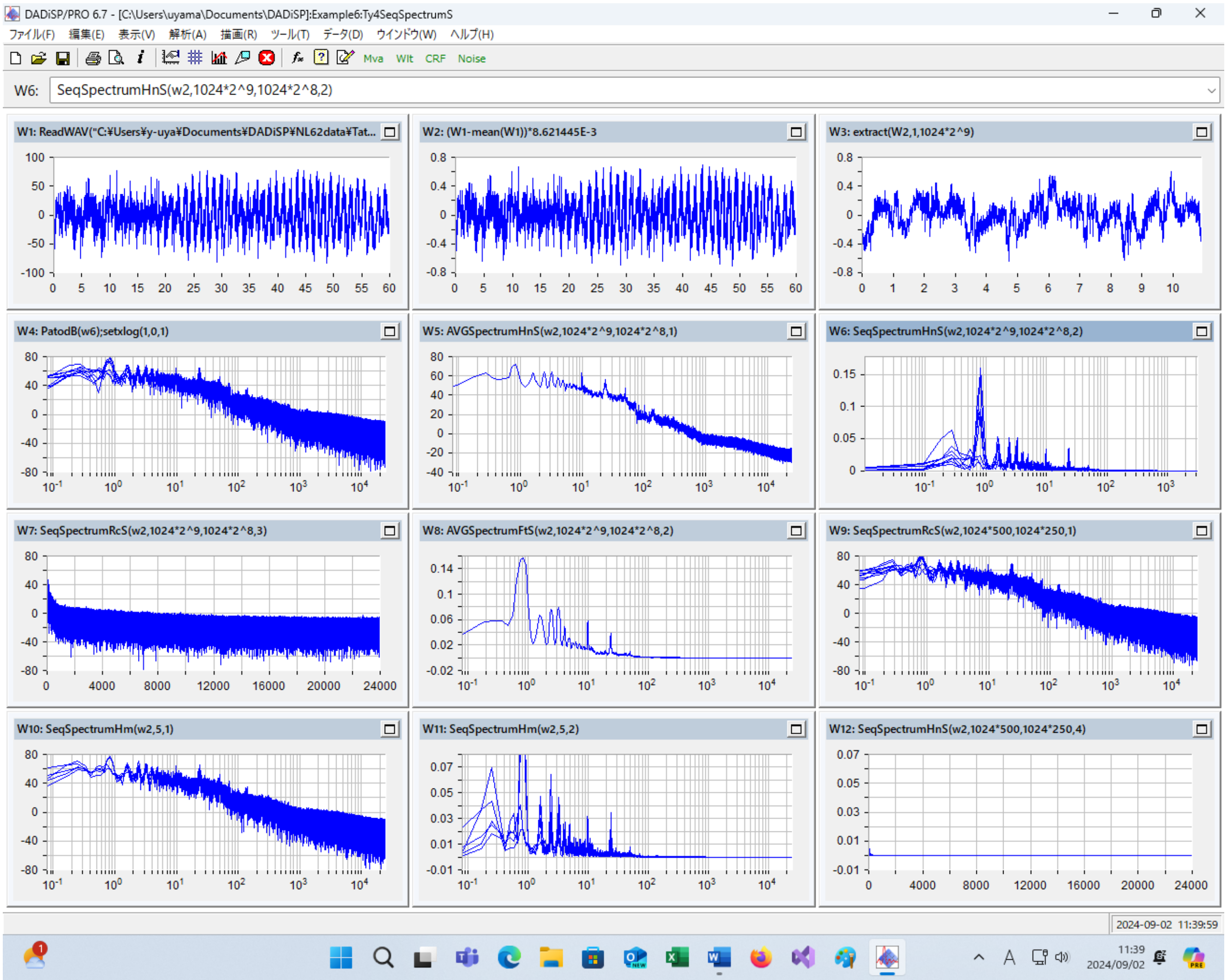
Ty4AVGSpectrum



- Sequence of frequency spectrum of the extracted data part



Ty4SeqSpectrumS



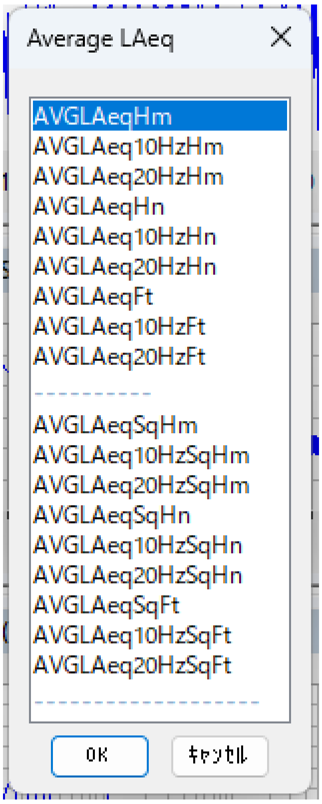
W6 : :SeqSpectrumHnS(w2,1024*2^9,1024*2^8,2)

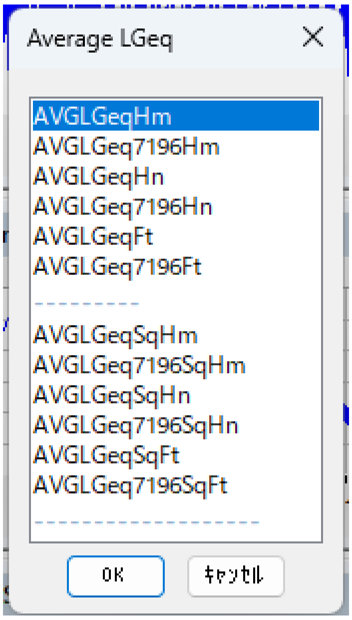
/* SeqSpectrumHnShift (2022.7.23) */
SeqSpectrumHnS(wpa,cl,s,w)

argument
WPA; Pascal value data
Cl;length of data to be cut out
S;starting position of the cutout
Option (1,2,3,4)

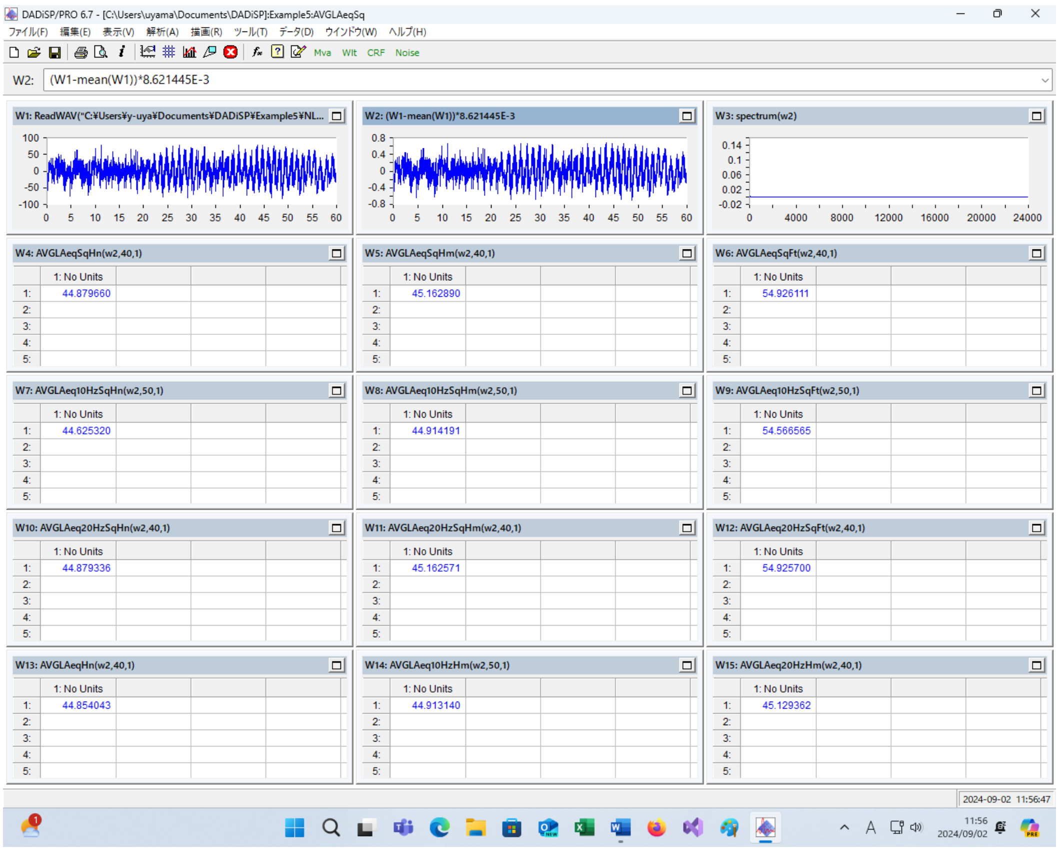
Functions of the function
From WPA, s*k+1(k=0,1,2,3... The data of the length cl is cut out, and the frequency spectrum of the cut data is calculated using the Hanning window, and the sequence is returned.
W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.
W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets
Ty4SeqSpectrumS


Average LAeq
AVGLAeqHm
AVGLAeq10HzHm
AVGLAeq20HzHm
AVGLAeqHn
AVGLAeq10HzHn
AVGLAeq20HzHn
AVGLAeqFt
AVGLAeq10HzFt
AVGLAeq20HzFt
AVGLAeqSqHm
AVGLAeq10HzSqHm
AVGLAeq20HzSqHm
AVGLAeqSqHn
AVGLAeq10HzSqHn
AVGLAeq20HzSqHn
AVGLAeqSqFt
AVGLAeq10HzSqFt
AVGLAeq20HzSqFt
OK
ｷｬﾝｾﾙ


Average LGeq
AVGLGeqHm
AVGLGeq7196Hm
AVGLGeqHn
AVGLGeq7196Hn
AVGLGeqFt
AVGLGeq7196Ft
AVGLGeqSqHm
AVGLGeq7196SqHm
AVGLGeqSqHn
AVGLGeq7196SqHn
AVGLGeqSqFt
AVGLGeq7196SqFt
OK
ｷｬﾝｾﾙ

AVGLAeqSq


W2: (W1-mean(W1))*8.621445E-3
W3: spectrum(w2)
W4: AVGLAeqSqHn(w2,40,1)
44.879660
W5: AVGLAeqSqHm(w2,40,1)
45.162890
W6: AVGLAeqSqFt(w2,40,1)
54.926111
W7: AVGLAeq10HzSqHn(w2,50,1)
44.625320
W8: AVGLAeq10HzSqHm(w2,50,1)
44.914191
W9: AVGLAeq10HzSqFt(w2,50,1)
54.566565
W10: AVGLAeq20HzSqHn(w2,40,1)
44.879336
W11: AVGLAeq20HzSqHm(w2,40,1)
45.162571
W12: AVGLAeq20HzSqFt(w2,40,1)
54.925700
W13: AVGLAeqHn(w2,40,1)
44.854043
W14: AVGLAeq10HzHm(w2,50,1)
44.913140
W15: AVGLAeq20HzHm(w2,40,1)
45.129362

/* AVGLAeq20HzSqHanning (2022.7.23) */
AVGLAeq20HzSqHn(wpa,nn,w)

argument
WPA; Pascal value data
Nn;Number of times to take the average
W;Optional (1 or 2)

Functions of the function
If w=1
Divide the data wpa of Pascal values into nn pieces. While using a hanning window for each divided data, the A-weighted sound pressure level is determined by weighting from 20 Hz.$L_{20,A,n}$

$$L_{20,A,n} = 20 * log10(\frac{P_{20,A,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{20,A,n}$

$(P_{20,A,T})^\wedge 2 = ((P_{20,A,1})^\wedge 2 + (P_{20,A,2})^\wedge 2 + \cdots + (P_{20,A,nn})^\wedge 2)/nn$

It becomes, from,$P_{20,A,T}$

$$L_{20,A,T} = 20 * log_{10}(\frac{P_{20,A,T}}{0.00002})$$

and return this value.

The formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

It is a calculation close to that.

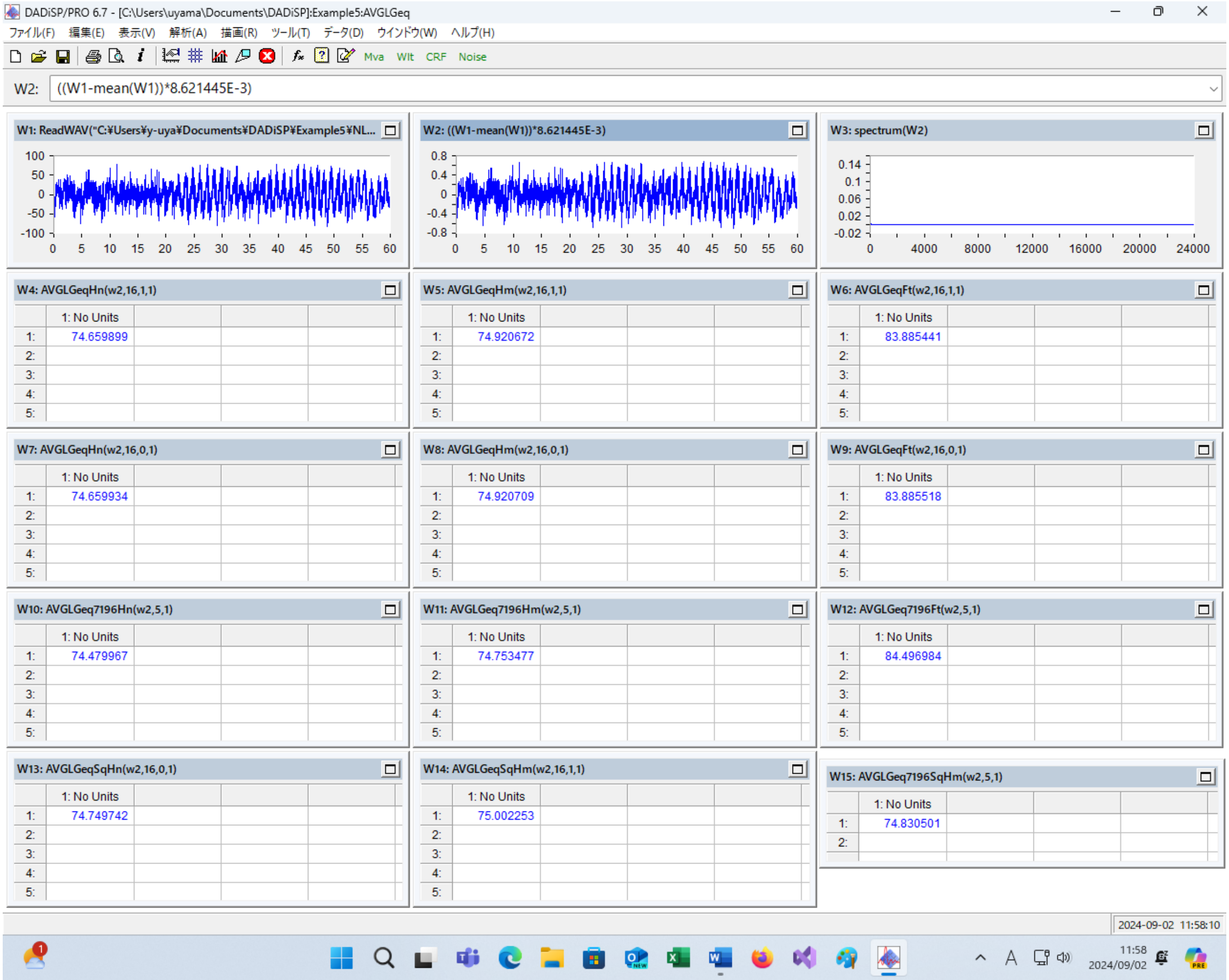
If w=2
Divide the data wpa of Pascal values into nn pieces. For each divided data, use the Hanning window to calculate spectrum(), cut out the components in the range of frequencies (20Hz~20kHz) handled by weighting from 20Hz, and obtain the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers.$P_{20,p,T}$

$$L_{20,P,T} = 20 * log_{10}(\frac{P_{20,P,T}}{0.00002})$$

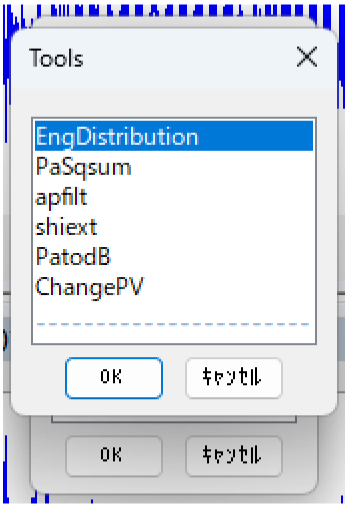
The weight is calculated as 0.

Reference worksheets
AVGLAeqSq

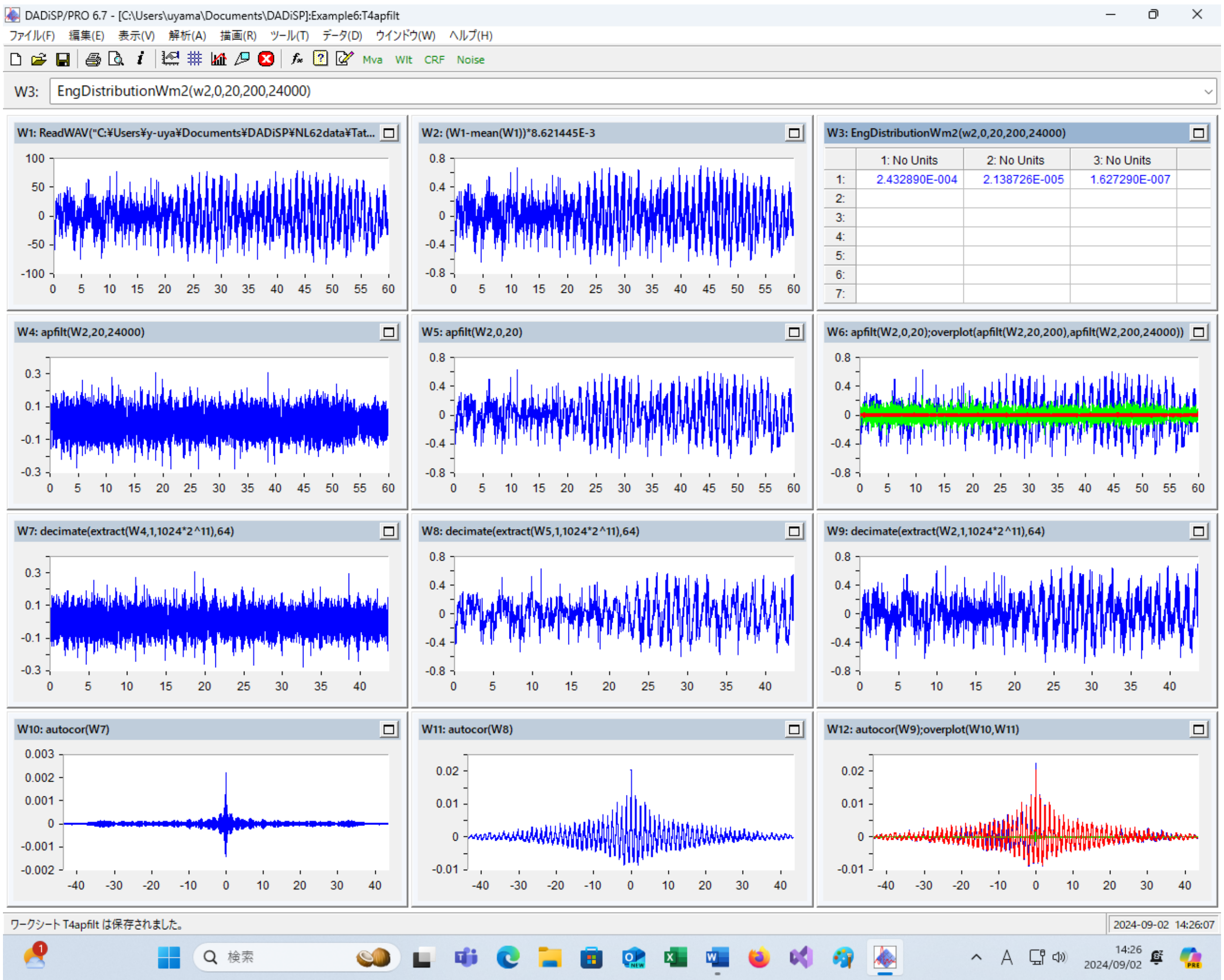
AVGLGeq


DADiSP/PRO 6.7 - [C:\Users\uyama\Documents\DADiSP]:Example5:AVGLGeq
ファイル(F) 編集(E) 表示(V) 解析(A) 描画(R) ツール(T) データ(D) ウインドウ(W) ヘルプ(H)
Mva Wlt CRF Noise
W2: ((W1-mean(W1))*8.621445E-3)
W1: ReadWAV("C:¥Users¥y-uya¥Documents¥DADiSP¥Example5¥NL...
W2: ((W1-mean(W1))*8.621445E-3)
W3: spectrum(W2)
W4: AVGLGeqHn(w2,16,1,1)
1: No Units
74.659899
W5: AVGLGeqHm(w2,16,1,1)
1: No Units
74.920672
W6: AVGLGeqFt(w2,16,1,1)
1: No Units
83.885441
W7: AVGLGeqHn(w2,16,0,1)
1: No Units
74.659934
W8: AVGLGeqHm(w2,16,0,1)
1: No Units
74.920709
W9: AVGLGeqFt(w2,16,0,1)
1: No Units
83.885518
W10: AVGLGeq7196Hn(w2,5,1)
1: No Units
74.479967
W11: AVGLGeq7196Hm(w2,5,1)
1: No Units
74.753477
W12: AVGLGeq7196Ft(w2,5,1)
1: No Units
84.496984
W13: AVGLGeqSqHn(w2,16,0,1)
1: No Units
74.749742
W14: AVGLGeqSqHm(w2,16,1,1)
1: No Units
75.002253
W15: AVGLGeq7196SqHm(w2,5,1)
1: No Units
74.830501
2024-09-02 11:58:10

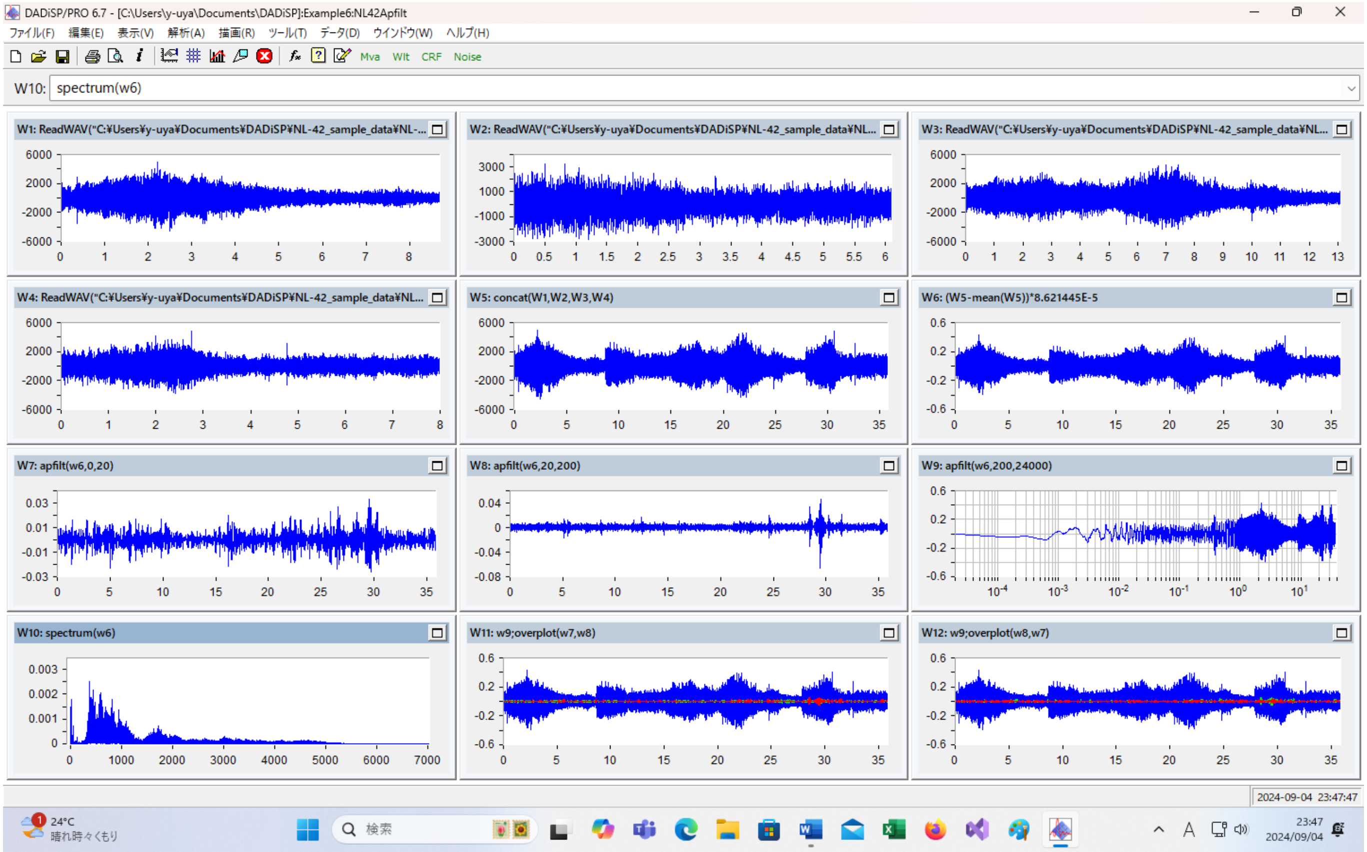
・Tools



Y4apfilt



NL42Apfilt


DADiSP/PRO 6.7 - [C:\Users\y-uya\Documents\DADiSP]:Example6:NL42Apfilt
ファイル(F) 編集(E) 表示(V) 解析(A) 描画(R) ツール(T) データ(D) ウインドウ(W) ヘルプ(H)
Mva Wlt CRF Noise
W10: spectrum(w6)
W1: ReadWAV("C:¥Users¥y-uya¥Documents¥DADiSP¥NL-42_sample_data¥NL-...
W2: ReadWAV("C:¥Users¥y-uya¥Documents¥DADiSP¥NL-42_sample_data¥NL...
W3: ReadWAV("C:¥Users¥y-uya¥Documents¥DADiSP¥NL-42_sample_data¥NL...
W4: ReadWAV("C:¥Users¥y-uya¥Documents¥DADiSP¥NL-42_sample_data¥NL...
W5: concat(W1,W2,W3,W4)
W6: (W5-mean(W5))*8.621445E-5
W7: apfilt(w6,0,20)
W8: apfilt(w6,20,200)
W9: apfilt(w6,200,24000)
W10: spectrum(w6)
W11: w9;overplot(w7,w8)
W12: w9;overplot(w8,w7)
2024-09-04 23:47:47
24°C
晴れ時々くもり
検索
23:47
2024/09/04

3.6 Evaluation of numerical values of measurement results

The Ministry of the Environment has published the following evaluation methods for low-frequency sound.

The numbers here are:

Regarding complaints related to mental and physical matters,

The measured quantity shall be the G-weighted sound pressure level (dB) and the 1/3 octave band sound pressure level (dB). $L_G L_{p,1/3oct}$

For physical complaints, the

1/3 octave band sound pressure level of the low-frequency sound is compared with Table 1, and if it is above the reference value, it is possible that the complaint is due to low-frequency sound.

As a general rule, the measurement frequency range is 1/3 octave band center frequency of 1Hz~80Hz.

And there is,

You can see that the values in the table are for the flatness characteristics (not weighted by A or G characteristics).

L_G =92 dB is the overall value in the G characteristics.

2.1　物的苦情に関する参照値

低周波音による物的苦情に関する参照値は、表１とする。

表１　低周波音による物的苦情に関する参照値

1/3 ｵｸﾀｰﾌﾞﾊﾞﾝﾄﾞ 中心周波数(Hz)	5	6.3	8	10	12.5	16	20	25	31.5	40	50
1/3 ｵｸﾀｰﾌﾞﾊﾞﾝﾄﾞ 音圧レベル(dB)	70	71	72	73	75	77	80	83	87	93	99

2.2　心身に係る苦情に関する参照値

低周波音による心身に係る苦情に関する参照値は、表２及び G 特性音圧レベル L_G=92(dB)とする。

表２　低周波音による心身に係る苦情に関する参照値

1/3 ｵｸﾀｰﾌﾞﾊﾞﾝﾄﾞ 中心周波数(Hz)	10	12.5	16	20	25	31.5	40	50	63	80
1/3 ｵｸﾀｰﾌﾞﾊﾞﾝﾄﾞ 音圧レベル(dB)	92	88	83	76	70	64	57	52	47	41

Here

2.2　心身に係る苦情に関する参照値

低周波音による心身に係る苦情に関する参照値は、表２及び G 特性音圧レベル L_G=92(dB)とする。

It says "G-weighted sound pressure level LG = 92 (dB).", but the calculation method of this value is the same

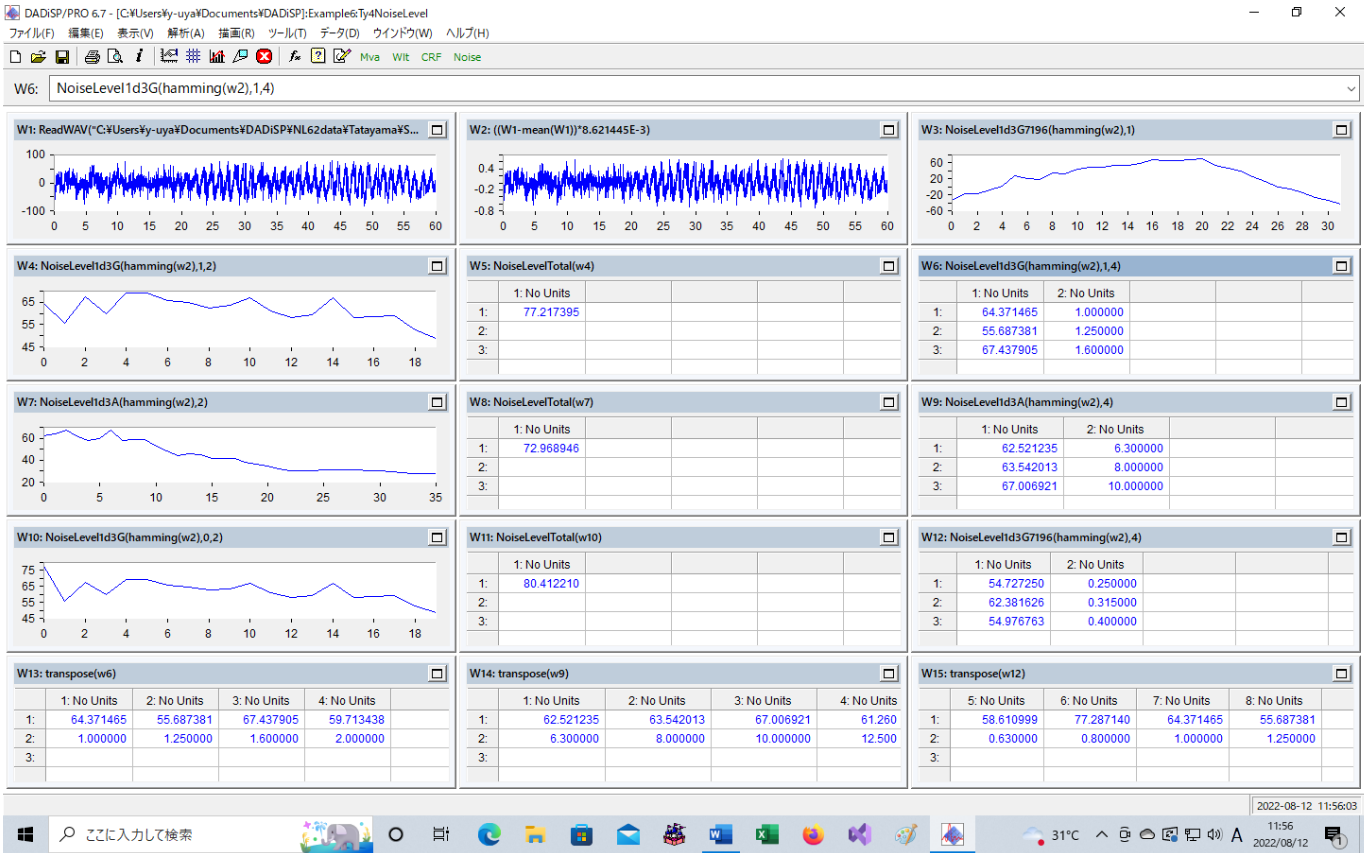
as the standard value of 100dB. This figure of 92 dB and the description of the ISO7196, "Weighted sound pressure levels which fall below about 90 dB will not normally be significant for human perception.""(Frequency) weighted sound pressure levels below about 90 dB are generally not significant (or perceived) for human cognitive function."
has consistency.

The reference value indicates the threshold (boundary value) at which discomfort is felt, including senses other than hearing. When it comes to infrasound sounds, hearing is dull, but the other human senses grasp the effects of infrasound before hearing.

The reference value is the sound pressure level that 10% of people find uncomfortable. For a lower 90 dB, ISO7196 writes as above.

Numerical calculations are

Ty4NoiseLevel



If the last argument is set to 4, the sound pressure level in the flat characteristic is displayed to the left of the center frequency.

Since it is before weighting, the value is the same for both G and A characteristics.

W13: transpose(w6)

	1: No Units	2: No Units	3: No Units	4: No Units
1:	64.371465	55.687381	67.437905	59.713438
2:	1.000000	1.250000	1.600000	2.000000
3:				

W14: transpose(w9)

	1: No Units	2: No Units	3: No Units	4: No Units
1:	62.521235	63.542013	67.006921	61.260
2:	6.300000	8.000000	10.000000	12.500
3:				

In the A characterization, the center frequency is 6.8 Hz, 10 Hz, 20 Hz or more, so to obtain the value of the flat characteristic for the center frequency of 5 Hz, use the G characteristic function.

W14: NoiseLevel1d3G(hamming(w2),0,4)

	1: No Units	2: No Units		
8:	64.719283	5.000000		
9:	62.521235	6.300000		
10:	63.542013	8.000000		

W15: NoiseLevel1d3G7196(hamming(w2),4)

	1: No Units	2: No Units	
14:	64.719283	5.000000	
15:	62.521235	6.300000	
16:	63.542013	8.000000	

This gives you the corresponding values in the table of reference values.

The following table also shows that the maximum sound pressure level at the flat characteristic is 77.287146 at a center frequency of 0.8 Hz.

W15: transpose(w12)

	5: No Units	6: No Units	7: No Units	8: No Units	
1:	58.610999	77.287140	64.371465	55.687381	
2:	0.630000	0.800000	1.000000	1.250000	
3:					

Since the natural frequency of houses in Japan is about 1 Hz and the components of frequencies of about 0.5 Hz have become more energetic due to the increase in the size of wind turbines, it is necessary to extend the range of reference values for physical complaints from 0.25 Hz to 315 Hz in accordance with ISO-7196.

According to the Ministry of the Environment, "In the case of large-scale wind turbines for power generation, the number of blades is generally 1~3 (mainly 3), the rotation speed is about 30~60 (rpm), and **the basic frequency is a few Hz** or less. Gone are the days of saying.

Recent wind turbines have a rated output of 42000 kW and a rotational speed of 10.8 rpm during rated operation, and the frequency is calculated by the Ministry of the Environment, which is 10.8 * 3 / 60 = 0.54 Hz.

"As a general rule, the measurement frequency range should be 1/3 octave band center frequency of 1Hz~80Hz."

It does not fit the current situation.

In order to make it easier to compare with the previous figures, I think it is better to calculate while changing the lower frequency of the bandpass filter with a center frequency of 1 Hz appropriately.

Numerical value at the original lower frequency limit Numerical value with the lower limit frequency at 0 Hz

W13: transpose(w6)

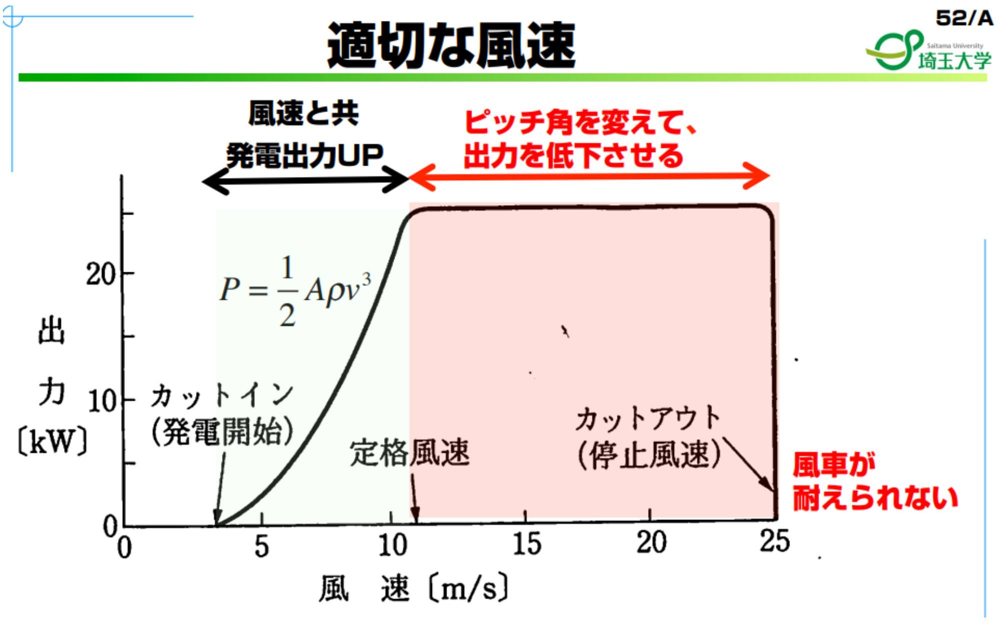
	1: No Units	2: No Units	3: No Units
1:	64.371465	55.687381	67.437905
2:	1.000000	1.250000	1.600000
3:			

W15: transpose(w12)

	1: No Units	2: No Units	3: No Units
1:	77.781611	55.687381	67.437905
2:	1.000000	1.250000	1.600000
3:			

In the case of reference values related to physical complaints, it is better to compare the results of measurements made using a sound level meter and vibration level meter together indoors with the data used when humans detect shaking during an earthquake.

According to the website of the Ministry of the Environment,
Q9 Is the "reference value" not applicable to wind turbines (wind power generation)?
A9 "Reference value" is set for low-frequency sounds with small fluctuations in sound pressure levels from a fixed sound source that continuously generates low-frequency sound for a certain amount of time. [Noise and low-frequency sound from wind turbines are characterized by changes in sound pressure level and frequency characteristics due to changes in rotor rotation and output depending on wind speed, and changes in the direction in which sound is diffused depending on the wind direction]. For this reason, **it is not possible to apply a "reference value" to the low-frequency sound of a wind-turbine.**
<Reference> Handling of Reference Values in the Guidebook for Dealing with Low-Frequency Sound Problems (Notice to Prefectural Governments, etc., April 20) [PDF 75KB]
There is also a description that
Many modern wind turbines change the pitch angle so that the rotor speed and output do not change even if the wind speed changes.
Energy Conversion Engineering Wind Power Generation(Yasuhiro Hasegawa Saitama Univ., Japan)



や、

CAE Solutions

東伊豆町風力発電所

Q 風車のまわるスピードは風が強くなるほど速くなるのですか。

A 風車の回転スピードは風の強さによって2段階に切り替ります。
風速3m/sから5.5m/sの間は低速(17回転/分)で回転します。
風速5.5m/sを超えると高速回転(25.5回転/分)に切り替り、それ以上は風がどんなに強くなっても回転数が一定になるように、翼の角度を変えて調整しています。
風車の発電機の種類などによっては風の強さによって回転数が変わるものもあります。

As you can see, the rotation speed and power of the wind-turbine are stable. Wind-turbines with varying rotations and power output are in the minority. The contents of the website must also be changed according to the times.

3.7 The enormity of wind-turbines and G characteristics

Previously, the Ministry of the Environment
"The principle of generating infrasound in a wind turbine is basically similar to the so-called rotational sound of a blower. In the case of a large-scale wind turbine for power generation, the number of blades is small and the rotation speed is small, so extremely low-frequency sound may be generated even in normal operation.
The fundamental frequency f (Hz) is when the number of revolutions of the blades is R (rpm) and the number of blades is Z (sheets).
f＝RZ/60 (Hz)
This fundamental frequency and its higher frequencies are preeminent.
In the case of large-scale wind turbines for power generation, the number of blades is generally 1~3 (mainly 3), the rotation speed is about 30~60 (rpm), and the fundamental frequency is a few Hz or less. “
He said.

The frequency of recent large-scale wind turbines is calculated by the Ministry of the Environment's frequency calculation method, **which is 10.8 * 3 / 60 = 0.54 Hz**, which cannot be measured using a precision sound level meter alone.
No matter how strong the sound at this frequency becomes, whether it is an A or G sound, it has almost no effect on the numerical value of the sound pressure level calculation. (I'll check the model later.))

The frequency of the strongest component of the sound with a frequency lower than 20 Hz is considered to be close to 0.54 Hz. Considering that a certain proportion of the wind energy is diffused as infrasound sound, the wind turbine in Tateyama has an output of 1500 kW, the length of the blade is 35.25 m, the area of the rotating surface is 3904 square meters, the output is 4200 kW, the length of the blade is 68 m, the area of the rotating surface is 14527 square meters, and if the wind energy is compared with the rotating surface, it is 3.7 times, If you compare it in terms of output, it is 2.8 times.
The sound pressure of 0.8 Hz at Tateyama's wind-turbine is 0.3 pascals. Considering that the energy is proportional to the square of the sound pressure, the sound pressure of a large wind-turbine is p, and if (p^2) / (0.3) ^2 = 3.7, then p = 0.58 (Pa), if (p^2) / (0.3) ^2 = 2.8, then p = 0.5 (Pa), and the sound pressure level is 87.96(dB) to 89.25 (dB).

Since the publication of ISO 7196:1995 in 1995 and ISO 389-7 in 1996, wind-turbines have grown exponentially in both size and power. This created a new problem.
Due to the increase in size, the frequency of the sound from the wind-turbine, which has a lot of energy, drops sharply, and is treated as almost 0 in the calculation of the G-weighted sound pressure level. The result of the calculation is far from the state of the sound energy emitted by the wind-turbine.

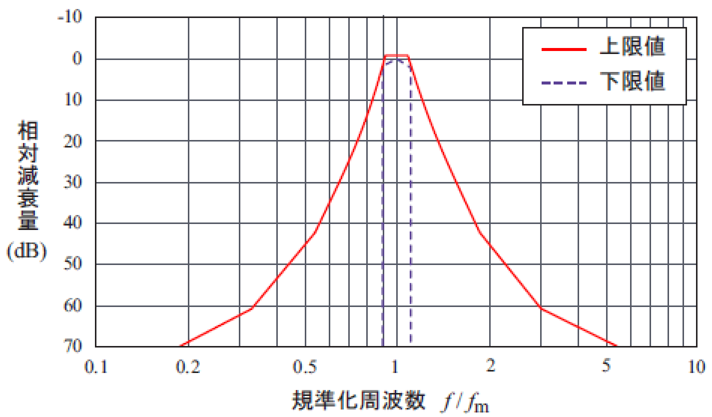
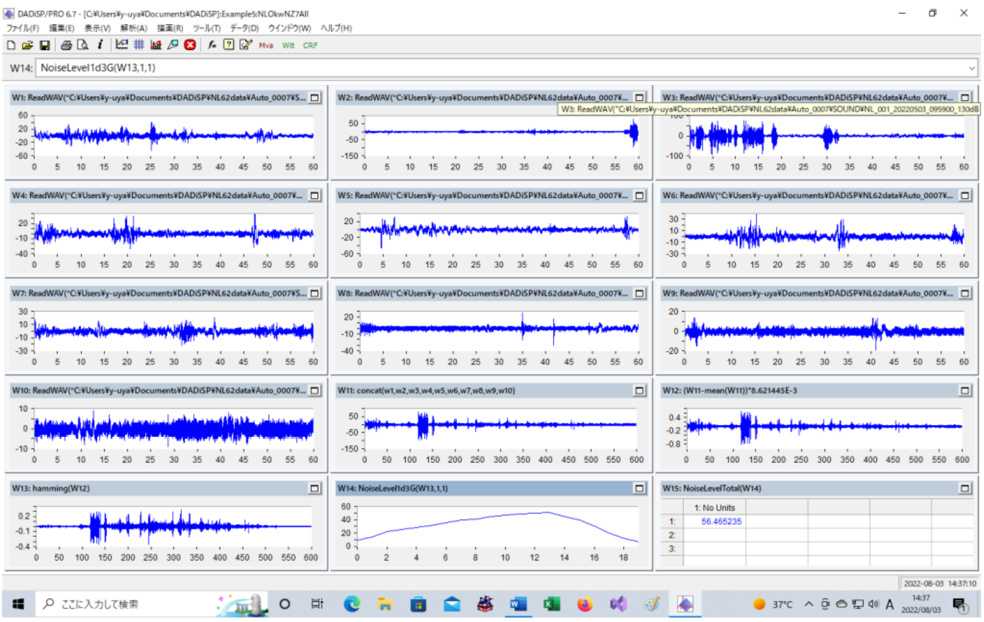


図 11-5　1/3 オクターブバンドフィルタ クラス 1 の相対減衰量の限界値

In the case of a center frequency of 1 Hz (0.9765625 Hz), the lower frequency limit is 0.870018 Hz and the upper frequency is 1.096154 Hz.
Even if the 0.54 Hz component is caught at the slope of the bandpass filter, it is treated as almost 0 in the calculation.

The noise measured in the precincts of the shrine shows that the data when someone was using a mower nearby.
The G-weighted sound pressure level calculated at the 1/3 octave band center frequency of 1-80Hz was 56.465235.

NLOkwNZ7All　(WAV files in Auto_0007.mh loaded in numerical order)
(I removed it because it was too large.) ）



This value is almost the same as in the case of noise (3).

予測地点	時間区分	G特性音圧レベル（L_{Geq}）				超低周波音を感じる最小音圧レベル
		現況値	風力発電施設寄与値	将来予測値	増加分	
		a	本事業	b	b-a	（ISO-7196:1995）
騒音－③	昼間	59	61	63	4	
	夜間	54		62	8	
	全日	58		63	5	

I would like to add the effect of the band-pass filter and the effect of the G-weighting on the G-weight.

Let's check the case of a center frequency of 1 Hz with G characteristics.

At a frequency of 0.5 Hz

In the case of a center frequency of 1 Hz, f/fm = 0.5/1 = 0.5 for a 0.5 Hz wave, and the relative attenuation due to the filter is about 45 dB in class 1.

Suppose this was when a 0.5Hz wave, entered this filter, and came out, $Asin(0.5 * 2\pi\ t)$ $Bsin(0.5 * 2\pi\ t)$

$$10 * log_{10}\left(\frac{A^2}{P_0^2}\right) - 10 * log_{10}\left(\frac{B^2}{P_0^2}\right) = 45$$

$20 * log_{10}\left(\frac{A}{B}\right) = 45$Therefore, A/B=10^2.25=178, so B=A/178.

Therefore, the 0.5 Hz component in the wave after passing through the filter is treated as having an amplitude of only 1/178 of the original magnitude in the calculation of noise in this band.

Correction by G-characteristic

For the band with a center frequency of 1 Hz, -45 dB correction is applied, so the amplitude evaluation is further reduced, and its magnitude is

C/B = 10^ (-45/20) = 0.0056. $20 * log_{10}\left(\frac{C}{B}\right) = -45$

Because the final amplitude rating will be 0.0056*0.0056=0.0000316 times the original amplitude It's like,

$$Asin(0.5 * 2\pi\ t)$$

Waves of

$$0.0000316 * Asin(0.5 * 2\pi\ t)$$

They are treated as if they were.

At a frequency of 0.2 Hz

In the case of a center frequency of 1 Hz, f / fm = 0.2 / 1 = 0.2 for a wave of 0.2 Hz, and the relative attenuation is about 70 dB in class 1.

It was when the 0.2Hz wave, went into this filter, and came out and when$Asin(0.2 * 2\pi\ t)$ $Bsin(0.2 * 2\pi\ t)$

$$10 * log_{10}\left(\frac{A^2}{P_0^2}\right) - 10 * log_{10}\left(\frac{B^2}{P_0^2}\right) = 70$$

$20 * log_{10}\left(\frac{A}{B}\right) = 70$Therefore, A/B=10^3.5=3162

Therefore, B = A / 3162.
Therefore, the 0.2 Hz component in the wave after passing through the filter is treated as having only an amplitude of 1/3162 = 0.000316 of the original amplitude in the calculation of noise in this band.

Correction by G-characteristic
In the case of the G characteristic, -45 dB correction is applied for the band with a center frequency of 1 Hz, so the strength is C / B = 10 ^ (-45 / 20) = 0.0056 for the overall noise level. $20 * log_{10}\left(\frac{C}{B}\right) = -45$
In the calculation of the overall noise intensity, it is 0.0056*0.000316=0.00000177.
It's like,

$$Asin(0.2 * 2\pi\ t)$$

Waves of

$$0.00000177 * Asin(0.2 * 2\pi\ t)$$

They are treated as if they were.

Let's also calculate the 0.8Hz component confirmed by the measurement.
At a frequency of 0.8 Hz
In the case of a center frequency of 1 Hz, f / fm = 0.8 / 1 = 0.8 for a wave of 0.8 Hz, and the relative attenuation is about 15 dB in class 1.
It was when the 0.8Hz wave, came into this filter, and when it came out, $Asin(0.8 * 2\pi\ t)$ $Bsin(0.8 * 2\pi\ t)$

$$10 * log_{10}\left(\frac{A^2}{P_0^2}\right) - 10 * log_{10}\left(\frac{B^2}{P_0^2}\right) = 15$$

$20 * log_{10}\left(\frac{A}{B}\right) = 15$Therefore, A/B = 10^0.75 = 5.6
Therefore, B = A / 5.6.
Therefore, the 0.8 Hz component in the wave after passing through the filter is treated as having only an amplitude of 1/5.6 = 0.179 of the original amplitude in the calculation of noise in this band.

Correction by G-characteristic
In the case of the G characteristic, -45 dB correction is applied for the band with a center frequency of 1 Hz, so the strength is C / B = 10 ^ (-45 / 20) = 0.0056 for the overall noise level. $20 * log_{10}\left(\frac{C}{B}\right) = -45$
In the calculation of the overall noise intensity, 0.179 * 0.0056 = 0.001

$$0.001 * Asin(0.8 * 2\pi\ t)$$

They are treated as if they were.

From the above, in the calculation with the G characteristics, the frequency components lower than 1 Hz are calculated as if there were only 1/1000 (8 Hz) to 1/30000 (0.5 Hz) to 1/565000 (0.2 Hz) intensities due to the influence of the bandpass filter with a center frequency of 1 Hz and the correction value of the G characteristics.

In the G-characteristic correction value, the frequency band between 10 Hz and 30 Hz is positively evaluated, so this part contributes greatly to the measurement results.

From the calculations so far, it is clear that the influence of extremely low frequency sound of 1 Hz or less emitted from the wind turbine contributes little to the calculation of the measurement results at the G characterization.

The evaluation of low-frequency sound with G characteristics alone cannot elucidate the various problems caused by infrasound below 1 Hz, which varies greatly before and after the construction of wind turbines. The effect is underestimated by the filter, and further reduced by the correction with the G-characteristics.

For example, even if there is an extremely low frequency sound with a strength of 1000 pascals at 0.2 Hz, it is treated as a wave with an amplitude of about 1000 / 565000 = 0.00177 pascals in the calculation with G characteristics.

Since 1 pascal is such a pressure that 1 N is applied to an area of 1 m^2, a force of 1000 N is applied to 1 m^2. Since a force (gravitational force) of 9.8 N acts on a substance with a mass of 1 kg on Earth, 1000/9.8 = 102, which is equivalent to adding 102 kg of weight per square meter of horizontal surface.

This is calculated according to the G characteristics, which is 0.00177 / 9.8 = 0.00018, and it is treated as if a weight of 0.00018 kg = 0.18 g is added.

Using Excel, create a simple model and check it again.

If we decide to use ISO7196 weights and create a simplified model, we get the following:

The sound pressure of each frequency was adjusted so that the overall G-weighted sound pressure level was 56.46126558dB.

Next, the sound pressure of the frequency component was changed so that the overall G-weighted sound pressure level was approximately 61dB.

If we evaluate the result in terms of the ratio of sound pressure,

When the 20Hz component changed from 0.0041 (Pa) to 0.008 (Pa), it became 61 (dB).

0.008/0.0041=1.95 times

When the 2 Hz component changed from 0.0005 (Pa) to 0.5 (Pa), it became 61 (dB).

0.5/0.0005=1000 times

When the 0.5 Hz component changed from 0.0002 (Pa) to 31.5 (Pa), it became 61 (dB).

31.5/0.0002=157500 times

When the 0.25 Hz component changed from 0.00024 (Pa) to 482 (Pa), it became 61 (dB).

482/0.00024=2008333 times

Are.

The results of the calculations are shown in the following table

	G特性音圧レベルの試算		ISO7196の重み付け					
	基準音圧（Pa）	0.00002						
	周波数（Hz）	0.25	0.5	1	2	10	20	50
	音圧（Pa）	0.00024	0.0002	0.0001	0.0005	0.0066	0.0041	0.0000007
①	騒音レベル（dB）（平坦特性）	21.5836249	20	13.9794001	27.9588002	50.3702788	46.2350772	-29.118639
②	G特性の重み付け	-88	-64.3	-43	-28.3	0	9	-20
①+②	G特性重み付け後	-66.416375	-44.3	-29.0206	-0.3411998	50.3702788	55.2350772	-49.118639
	G特性音圧レベル（dB）	56.46126558						
	周波数（Hz）	0.25	0.5	1	2	10	20	50
	音圧（Pa）	0.00024	0.0002	0.0001	0.0005	0.0066	0.008	0.0000007
①	騒音レベル（dB）（平坦特性）	21.5836249	20	13.9794001	27.9588002	50.3702788	52.0411998	-29.118639
②	G特性の重み付け	-88	-64.3	-43	-28.3	0	9	-20
①+②	G特性重み付け後	-66.416375	-44.3	-29.0206	-0.3411998	50.3702788	61.0411998	-49.118639
	G特性音圧レベル（dB）	61.39824356						
	周波数（Hz）	0.25	0.5	1	2	10	20	50
	音圧（Pa）	0.00024	0.0002	0.0001	0.5	0.0066	0.0041	0.0000007
①	騒音レベル（dB）（平坦特性）	21.5836249	20	13.9794001	87.9588002	50.3702788	46.2350772	-29.118639
②	G特性の重み付け	-88	-64.3	-43	-28.3	0	9	-20
①+②	G特性重み付け後	-66.416375	-44.3	-29.0206	59.6588002	50.3702788	55.2350772	-49.118639
	G特性音圧レベル（dB）	61.35819084						
	周波数（Hz）	0.25	0.5	1	2	10	20	50
	音圧（Pa）	0.00024	31.5	0.0001	0.0005	0.0066	0.0041	0.0000007
①	騒音レベル（dB）（平坦特性）	21.5836249	123.945611	13.9794001	27.9588002	50.3702788	46.2350772	-29.118639
②	G特性の重み付け	-88	-64.3	-43	-28.3	0	9	-20
①+②	G特性重み付け後	-66.416375	59.6456112	-29.0206	-0.3411998	50.3702788	55.2350772	-49.118639
	G特性音圧レベル（dB）	61.34928006						
	周波数（Hz）	0.25	0.5	1	2	10	20	50
	音圧（Pa）	482	0.0002	0.0001	0.0005	0.0066	0.0041	0.0000007
①	騒音レベル（dB）（平坦特性）	147.640341	20	13.9794001	27.9588002	50.3702788	46.2350772	-29.118639
②	G特性の重み付け	-88	-64.3	-43	-28.3	0	9	-20
①+②	G特性重み付け後	59.6403409	-44.3	-29.0206	-0.3411998	50.3702788	55.2350772	-49.118639
	G特性音圧レベル（dB）	61.3457206						

If you change the weighting of 1 Hz or less to the weight (-43) when all weights are 1 Hz and calculate the G-weighted sound pressure level, the following table is shown.

	G特性音圧レベルの試算		1Hzはローパスフィルタ（その①）					
	基準音圧（Pa）	0.00002						
	周波数（Hz）	0.25	0.5	1	2	10	20	50
	音圧（Pa）	0.00024	0.0002	0.0001	0.0005	0.0066	0.0041	0.0000007
①	騒音レベル（ｄB）（平坦特性）	21.5836249	20	13.9794001	27.9588002	50.3702788	46.2350772	-29.118639
②	G特性の重み付け	-43	-43	-43	-28.3	0	9	-20
①+②	G特性重み付け後	-21.416375	-23	-29.0206	-0.3411998	50.3702788	55.2350772	-49.118639
	G特性音圧レベル（ｄB）	56.4612657						

一部省略

	周波数（Hz）	0.25	0.5	1	2	10	20	50
	音圧（Pa）	0.00024	31.5	0.0001	0.0005	0.0066	0.0041	0.0000007
①	騒音レベル（ｄB）（平坦特性）	21.5836249	123.945611	13.9794001	27.9588002	50.3702788	46.2350772	-29.118639
②	G特性の重み付け	-43	-43	-43	-28.3	0	9	-20
①+②	G特性重み付け後	-21.416375	80.9456112	-29.0206	-0.3411998	50.3702788	55.2350772	-49.118639
	G特性音圧レベル（ｄB）	80.96104869						
	周波数（Hz）	0.25	0.5	1	2	10	20	50
	音圧（Pa）	482	0.0002	0.0001	0.0005	0.0066	0.0041	0.0000007
①	騒音レベル（ｄB）（平坦特性）	147.640341	20	13.9794001	27.9588002	50.3702788	46.2350772	-29.118639
②	G特性の重み付け	-43	-43	-43	-28.3	0	9	-20
①+②	G特性重み付け後	104.640341	-23	-29.0206	-0.3411998	50.3702788	55.2350772	-49.118639
	G特性音圧レベル（ｄB）	104.6404069						

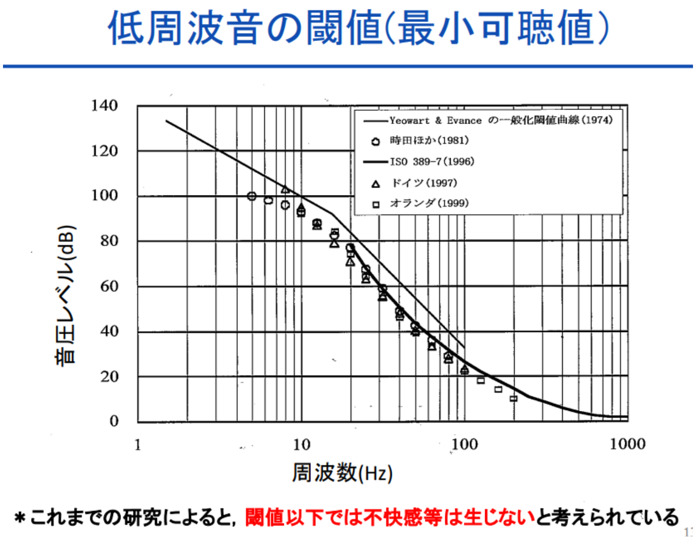
As a guideline for considering physical effects such as resonance, rather than auditory grasp, I think that the numerical values calculated in this way are more effective.

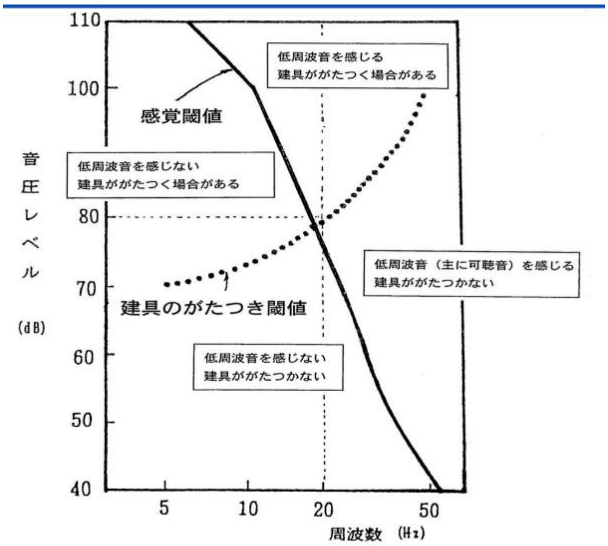
In this way, the following table shows the following table when the sound pressure of 61 (dB) is calculated by changing the part with a center frequency of 1 HZ to a low-pass filter up to 0 Hz.

	G特性音圧レベルの試算		1Hzはローパスフィルタ（その②）					
	基準音圧（Pa）	0.00002						
	周波数（Hz）	0.25	0.5	1	2	10	20	50
	音圧（Pa）	0.00024	0.0002	0.0001	0.0005	0.0066	0.0041	0.0000007
①	騒音レベル（ｄB）（平坦特性）	21.5836249	20	13.9794001	27.9588002	50.3702788	46.2350772	-29.118639
②	G特性の重み付け	-43	-43	-43	-28.3	0	9	-20
①+②	G特性重み付け後	-21.416375	-23	-29.0206	-0.3411998	50.3702788	55.2350772	-49.118639
	G特性音圧レベル（ｄB）			56.4612657				
	周波数（Hz）	0.25	0.5	1	2	10	20	50
	音圧（Pa）	0.00024	0.0002	0.0001	0.0005	0.0066	0.008	0.0000007
①	騒音レベル（ｄB）（平坦特性）	21.5836249	20	13.9794001	27.9588002	50.3702788	52.0411998	-29.118639
②	G特性の重み付け	-43	-43	-43	-28.3	0	9	-20
①+②	G特性重み付け後	-21.416375	-23	-29.0206	-0.3411998	50.3702788	61.0411998	-49.118639
	G特性音圧レベル（ｄB）			61.3982436				
	周波数（Hz）	0.25	0.5	1	2	10	20	50
	音圧（Pa）	0.00024	0.0002	0.0001	0.5	0.0066	0.0041	0.0000007
①	騒音レベル（ｄB）（平坦特性）	21.5836249	20	13.9794001	87.9588002	50.3702788	46.2350772	-29.118639
②	G特性の重み付け	-43	-43	-43	-28.3	0	9	-20
①+②	G特性重み付け後	-21.416375	-23	-29.0206	59.6588002	50.3702788	55.2350772	-49.118639
	G特性音圧レベル（ｄB）			61.35819088				
	周波数（Hz）	0.25	0.5	1	2	10	20	50
	音圧（Pa）	0.00024	3	0.0001	0.0005	0.0066	0.0041	0.0000007
①	騒音レベル（ｄB）（平坦特性）	21.5836249	103.521825	13.9794001	27.9588002	50.3702788	46.2350772	-29.118639
②	G特性の重み付け	-43	-43	-43	-28.3	0	9	-20
①+②	G特性重み付け後	-21.416375	60.5218252	-29.0206	-0.3411998	50.3702788	55.2350772	-49.118639
	G特性音圧レベル（ｄB）			61.96007148				
	周波数（Hz）	0.25	0.5	1	2	10	20	50
	音圧（Pa）	3	0.0002	0.0001	0.0005	0.0066	0.0041	0.0000007
①	騒音レベル（ｄB）（平坦特性）	103.521825	20	13.9794001	27.9588002	50.3702788	46.2350772	-29.118639
②	G特性の重み付け	-43	-43	-43	-28.3	0	9	-20
①+②	G特性重み付け後	60.5218252	-23	-29.0206	-0.3411998	50.3702788	55.2350772	-49.118639
	G特性音圧レベル（ｄB）			61.96007147				

I think it is useful to take the numerical values shown in the table above as a guide for physical vibration or sound pressure for recognizing discomfort with senses other than hearing.

It is difficult to produce 0.5 Hz, 1 Hz or 2 Hz sounds in a laboratory. Most experimental results are up to 5 Hz.
In the graph on the left, the line is cut off at 1.5 Hz. Circles and triangles are only up to 5 Hz. The graph on the right is also only up to 5Hz.





From the figure on the right, we **can see that as the frequency decreases, the rattling threshold also decreases.** When considering resonance, the problem is not so much the energy of the band, but the components that have outstanding strength in that band and the natural frequency of furniture.

The sound pressure in the band with a center frequency of 1 Hz is close to the natural frequency of Japan houses, so it is an important problem for people who sleep in the house. I don't think it is necessary to treat the rattling caused by a 1 Hz sound or the rattling caused by a 0.5 Hz sound with much difference when thinking about it physically.
Considering resonance, if the period of the force acting on the building coincides with the natural frequency, the vibration will increase even if a small force is applied periodically.

According to the website of the Ministry of the Environment,

> 建具の低周波音に対する反応は、低い周波数では人の感度よりも良く、揺れやすい窓や戸では、5Hzで70dB、20Hzで80dB程度の低周波音によってがたつく場合があります。

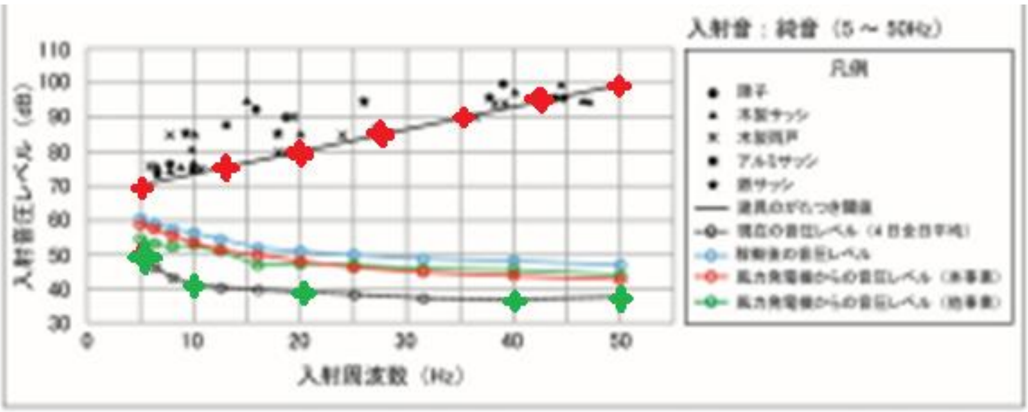
It is written.

It should be noted that "70 dB at 5 Hz and 80 dB at 20 Hz are used for windows and doors that are prone

to shaking."
In the case of a low frequency of 5 Hz, it is said that the joinery is likely to shake even with a weak sound of 70dB.

Now, let's compare the following two graphs. Both have a 1/3 octave band sound pressure level (flat characteristic).

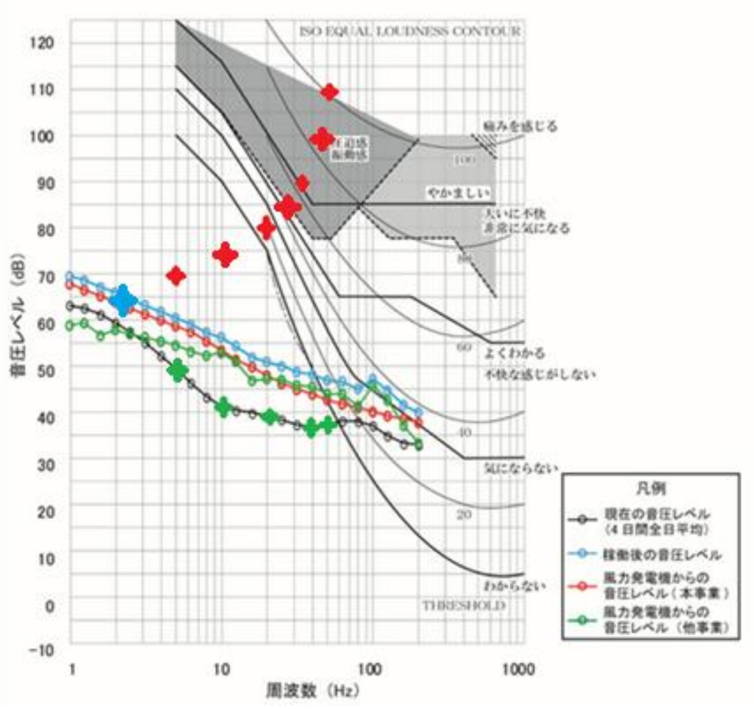
I marked the corresponding dots on the two graphs. These are the linear red dots in the top graph and the curved green dots below.



出典：「低周波音の測定方法に関するマニュアル」（環境庁大気保全局、平成12年）より作成

図 10.1.4-7(1) 建具のがたつきが始まるレベルとの比較結果

Now, in the graph above, the curve that was only up to 5 Hz extends to 1 Hz in the graph below.
However, the straight line in the figure above has disappeared, so I added a red mark. The red mark corresponds to the straight line of the rattling threshold.



出典：「文部省科学研究費『環境科学』特別研究：超低周波音の生理・心理的影響と評価に関する研究班『昭和55年度報告書 I 低周波音に対する感覚と評価に関する基礎研究』」より作成

図 10.1.4-8(1) 圧迫感・振動感を感じる音圧レベルとの比較結果

If you extend the red mark a little, you will bump into the blue mark.

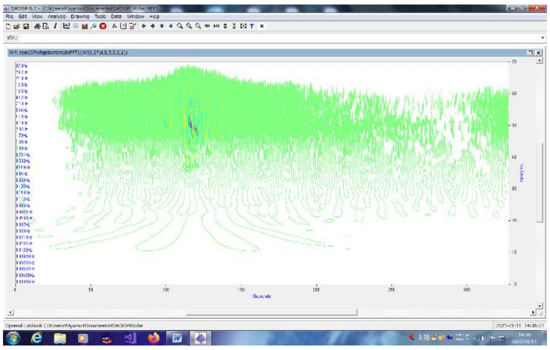
It is difficult to produce infrasound at 0.5 Hz or 1 Hz in the laboratory. Even if it is difficult in the laboratory, 0.5 Hz and 1 Hz sound exist in the vicinity of wind turbines in a high-energy form. If you install a precision sound level meter and a vibration level meter in the house where there is a wind-turbine, you can collect as much data as you want.

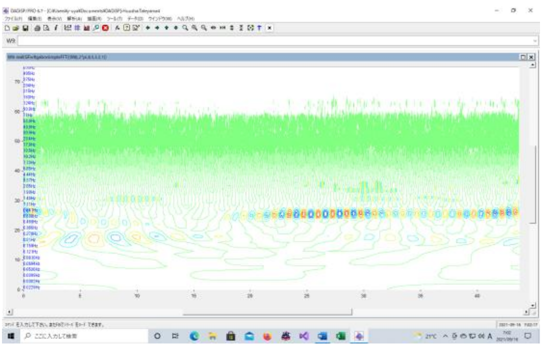
If something is rattling in the house, humans can perceive the rattling sound audibly, and they can sense the rattling shaking with their semicircular canals. Normal people sleep in the house, so if something in the house is rattled, they will sense it and sleep lightly.

For those who sleep in a house, resonance and resonance are also a concern. Let's compare the shaking of an earthquake with the sound of a wind-turbine.

On the left is the observation result in Mito City at the time of the Great Tohoku Earthquake. On the right is the noise data of the wind-turbine in Tateyama.

Mito Tateyama4

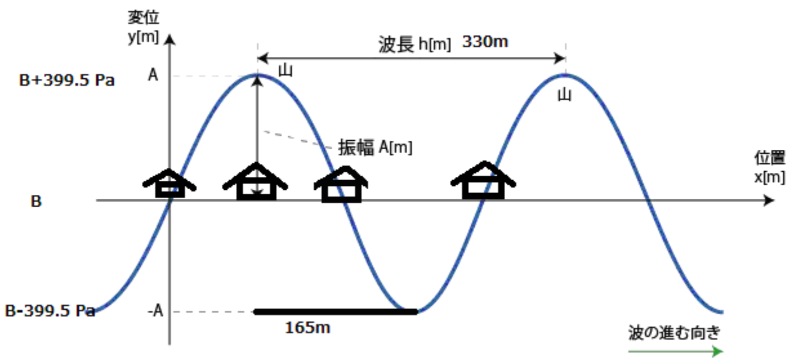




Both seismic waves and the infrasound of wind turbines contain frequency components with a natural frequency of about 1 Hz in Japan houses.

From the viewpoint of frequency stability, it can be said that wind turbines are more likely to cause large resonance phenomena when they match the natural frequency of buildings and fittings.

If you think about the state of the house that is pressured by sound,



It looks like the picture above, and the leftmost house is pushed from the right. The second house from the left is balanced on the left and right. The house on the far right is pushed from the right. The house can be pushed from the right or from the left. Periodic external forces are applied.

In order to investigate the impact on people living in houses in Japan, it is necessary to actively measure vibration and noise indoors.

Chapter 4 Causes and Frequencies of Wind-turbine Noise

4.1 Six phenomena to be explained

7.1.1 In the vicinity of wind-turbines, infrasound is measured even if the wind does not hit the microphone.

7.1.2 Without a wind-turbine, blowing wind on a microphone would not produce infrasound with high sound pressure.

7.1.3 Frequencies f/3, 2f/3, f, 2f, 3f、... The sound pressure increases at Hz

7.1.4 Wind-turbine sound directional and cross-type

7.1.5 Extremely low-frequency sound with high sound pressure was measured at 164 locations nationwide.

7.1.6 Frequency and sound pressure change according to wind speed

On the Canadian government's website, the introduction to noise says:

The X-axis of the graph represents frequencies from 0.1 hertz (Hz) to 100 Hz, while the Y-axis represents the intensity of the measured sound in decibels (dB). This figure shows an example of measurements taken on a clear summer night at a distance of 2.5 km from four wind turbines. The peaks of 0.8, 1.6, 2.4, 3.2, 4.0, 4.8, 5.6, 6.4, 7.2, and 8.0 Hz in the figure confirm that the measured sound is from a wind turbine, as these specific wind turbines are known to produce sound of these specific frequencies. Therefore, it should be possible to measure less than 0.8 Hz.

4.2 Theories about the causes of wind turbine sound

・ Matters to be considered

There are several views on the causes of wind-turbine noise. These views must be able to explain the nature of the wind-turbine sound described above.

In the past, the Ministry of the Environment

“4. Low-cycle Boeing prevention technology の summary

4.1.5 Wind-turbines

The principle of generating infrasound in wind turbines is basically similar to the so-called rotational sound of a blower. It has. In the case of large-scale wind turbines for power generation, the number of blades is small and the rotation speed is small, so it operates normally.

Even infrasound can be generated.

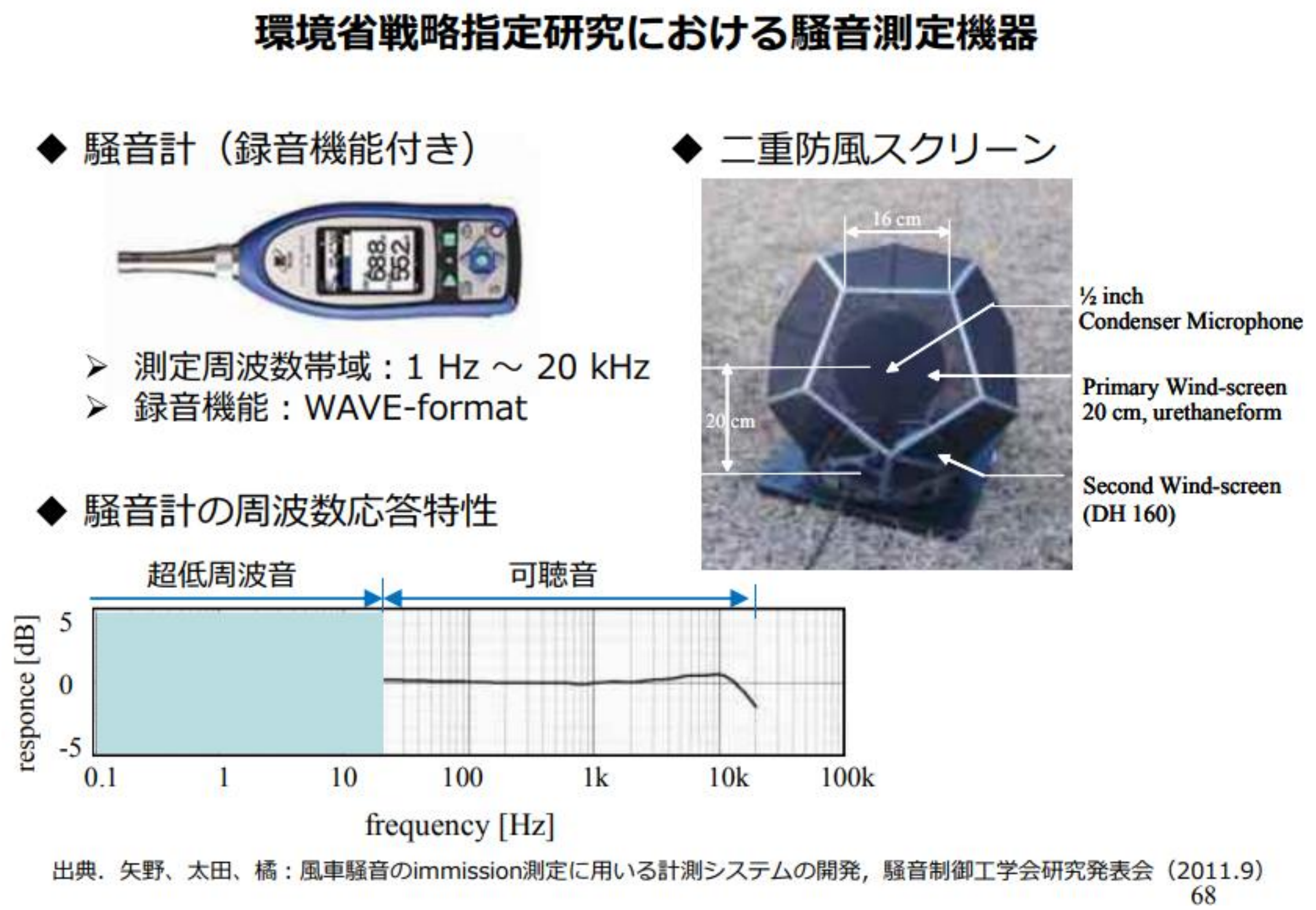
Its fundamental frequency f (Hz) is equal to R (rpm) and Z (sheet) as the number of blades

f ＝ RZ/60（Hz）

This fundamental frequency and its higher frequencies are preeminent.

In the case of large-scale wind turbines for power generation, the number of blades is generally 1~3 blades (mainly 3

blades), and the rotation speed is 30~60 (rpm)
and the fundamental frequency is a few Hz or less. “
(There are also overtones of the fundamental frequency.) ）
He said.
This means that a large wind turbine emits an extremely low frequency sound of f=RZ/60=0.5 (Hz).
So, can't this sound level meter measure infrasound at 0.5 Hz?
In addition, the center frequency at ISO7196 is 0.25Hz~315Hz. Is it impossible to perform a 1/3 octave analysis according to this?



The measurement frequency range of the sound level meter (with recording function) is 1Hz~20kHz. As it is, it is not possible to measure sound at 0.1 Hz or 0.2 Hz.
If you look at the diagram of the frequency response characteristics of the sound level meter, you can see that it is colored up to 0.1 Hz. In addition, Lion advertised that it would be possible to perform FFT analysis with additional software.
When I asked if it was possible to retrieve the sound pressure data before it was applied to the FFT, I was told that if I added a recording program, I could extract the data recorded at a sampling frequency of 48 kHz as a WAV file with the sound pressure as a 16-bit signed integer. I received a reply.
The minimum frequency of the frequency spectrum is only up to around 1 Hz with a sound level meter alone, but by treating this sound level meter as a device that records fluctuations in sound pressure, detailed fluctuations in sound pressure can be understood, and if it is examined with analysis software on a PC, a detailed state of the extremely low

frequency sound (0 Hz ~ 20 Hz) can be understood.

For 60 seconds of data, 48000 * 60 = 2880000 16-bit signed integers are given. You just need to calculate this. The amount of data is 5.76 MB.

In order to support high-frequency sounds while increasing the frequency resolution, it is possible to clarify the part of the infrasound (0Hz~20Hz) by increasing the sampling frequency and analyzing the data with a measurement time of 120 seconds or more.

The sound level meter in the figure above is a model that can obtain such data by adding it to a recording program.

With a sampling frequency of 48 kHz, long-term measurements are possible.

The microphone used is the same as the latest SA-A1, and we have obtained information from Lion that the numerical values in the file that records the sound pressure are the same as those of the SA-A1 and the NL-62.

If you have this, you can do the necessary calculations, but since the functions of the analysis software are insufficient, you need to make your own.

Calculations based on large amounts of data require a lot of memory and a high-performance CPU.

The sound level meter does not have that function. That's why you need a PC and analysis software.

There are many different views on wind-turbine sounds, but they all have one thing in common. Its characteristic is that it does not measure and analyze the low-frequency and infrasound-frequency sound of wind-turbines by itself.

Even if it is measured, it is almost always discussed by limiting it to 1 Hz or more, or limiting it to 20 Hz or more. Even if it says ISO7196, there is no discussion of the sound pressure level in the 0.25 Hz band.

I look up the literature, but I don't measure the low-frequency sound of the wind-turbine with the necessary accuracy and analyze it myself.

I'll post the graph again. Let's take a look at this and consider the various theories.

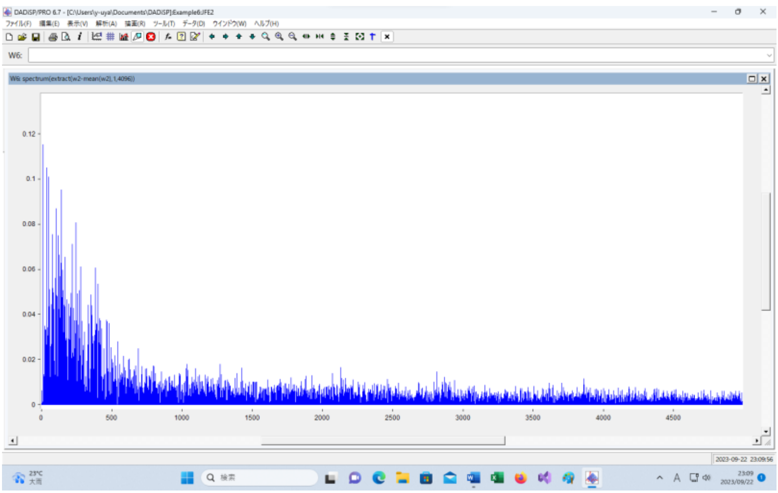


Fig.1 JFE の製鉄所内の音(0～5000Hz)；最大音圧 0.12[Pa](12Hz)

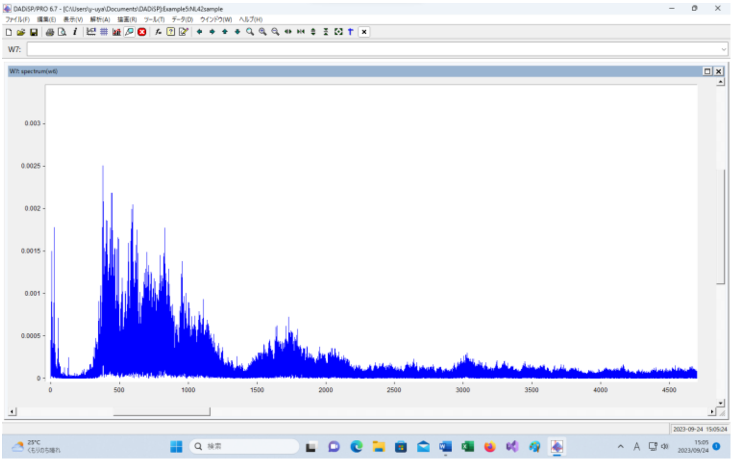


Fig.2 Noise on the road in front of Lion (0~5000Hz): Maximum sound pressure 0.0025[Pa] (379.4[Hz])

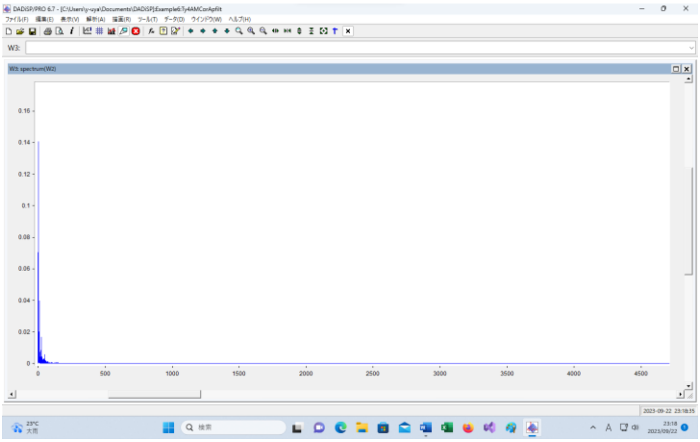


Fig.3 Sound measured near a wind-turbine (0~5000Hz); Maximum sound pressure 0.14 [Pa] (0.8Hz)

Next, in the range of 0~25Hz, we will compare the sound of wind-turbines with the sound of the nearby Nagao Shrine.

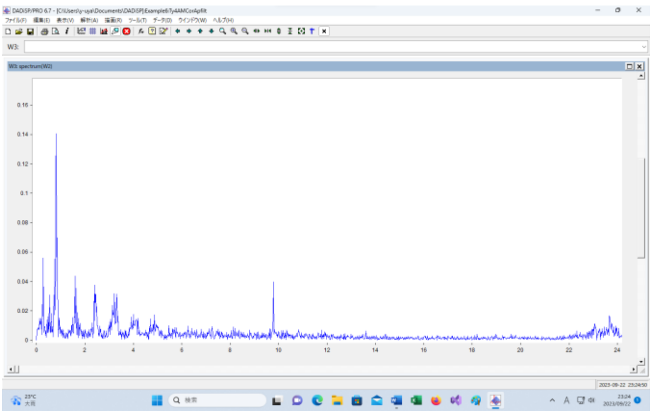


Fig.3 Sound measured near a wind-turbine (0~25Hz); Maximum sound pressure 0.14 [Pa] (0.8Hz)

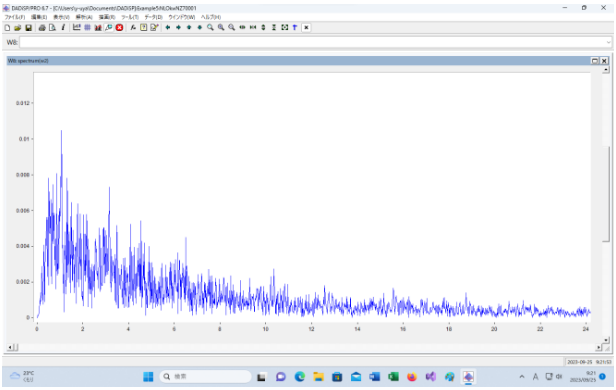
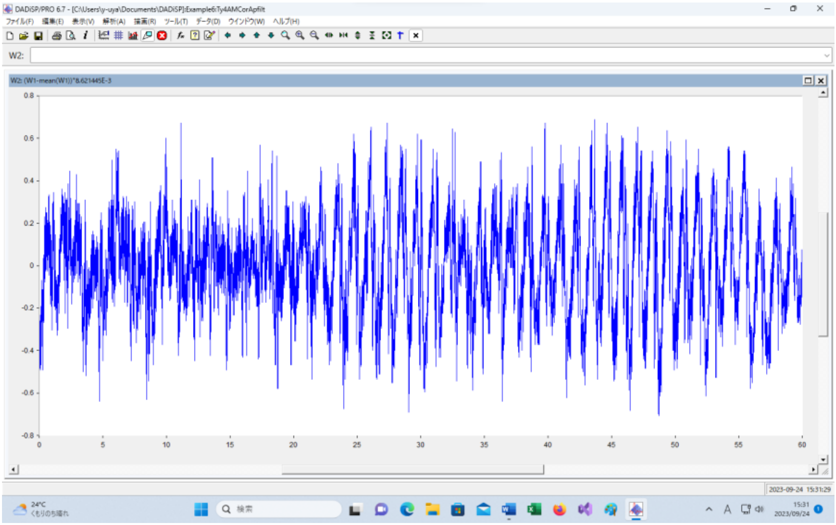


Fig.4 長尾神社境内の音(0～25Hz); 最大音圧 0.0105[Pa](1.1Hz)

A lot of people are talking about amplitude modulation, but they don't use FFT to take a component above 100 Hz or even 200 Hz and compare the amplitude modulation of that component with the amplitude of the infrasound region.

The graph of wind-turbine sounds is as follows:



The sound of the wind-turbine is divided into components of 0~20Hz for blue, 20~200Hz for green, and 200~24kHz for red.

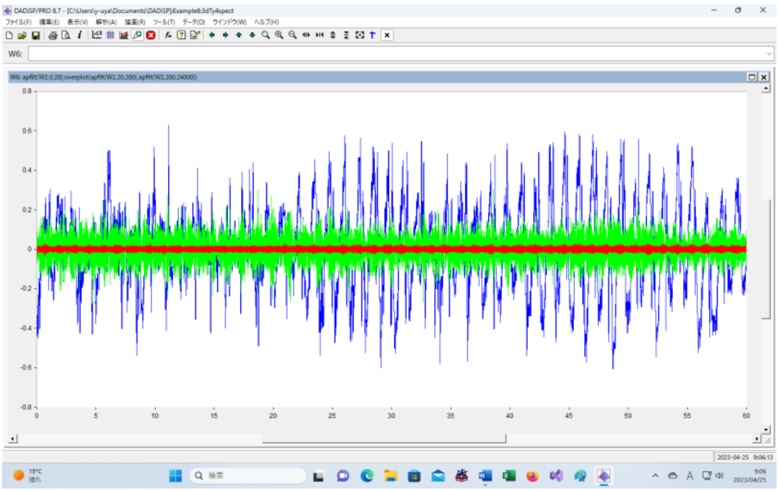


Fig.5 Separated Wind-turbine noise

Furthermore, it does not properly state what frequency of sound is generated by what kind of motion is generated by wind-turbine sound.

In order to think about how wind-turbine noise is generated, it is important to pay attention to the detailed characteristics of wind-turbine sound.

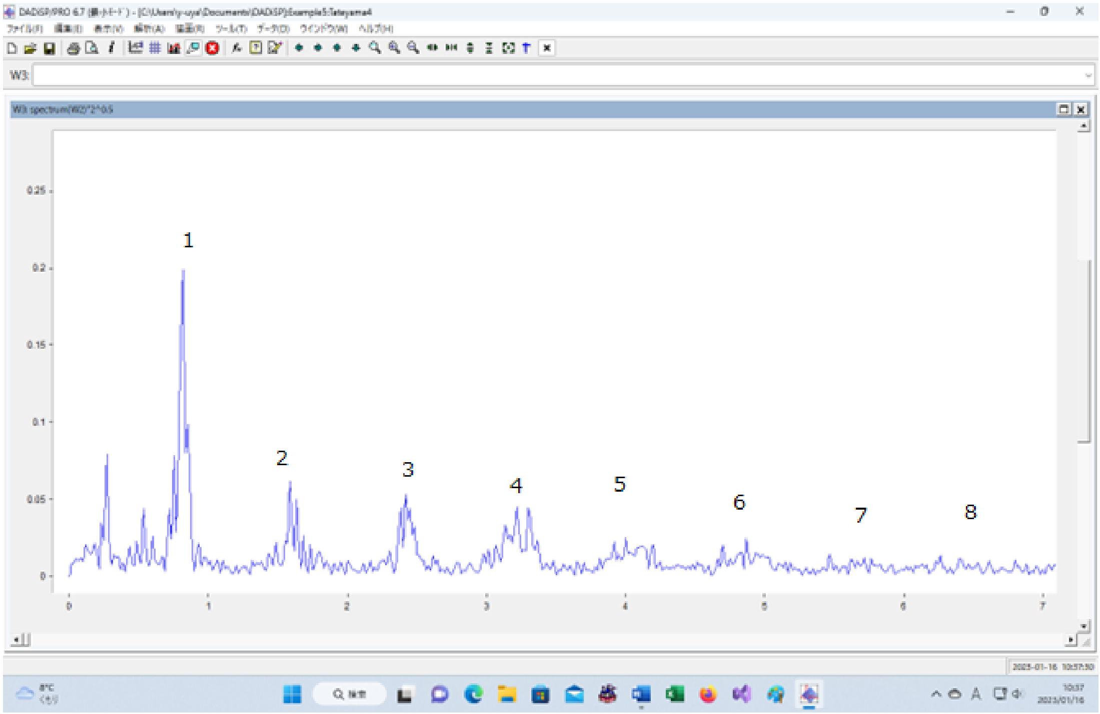


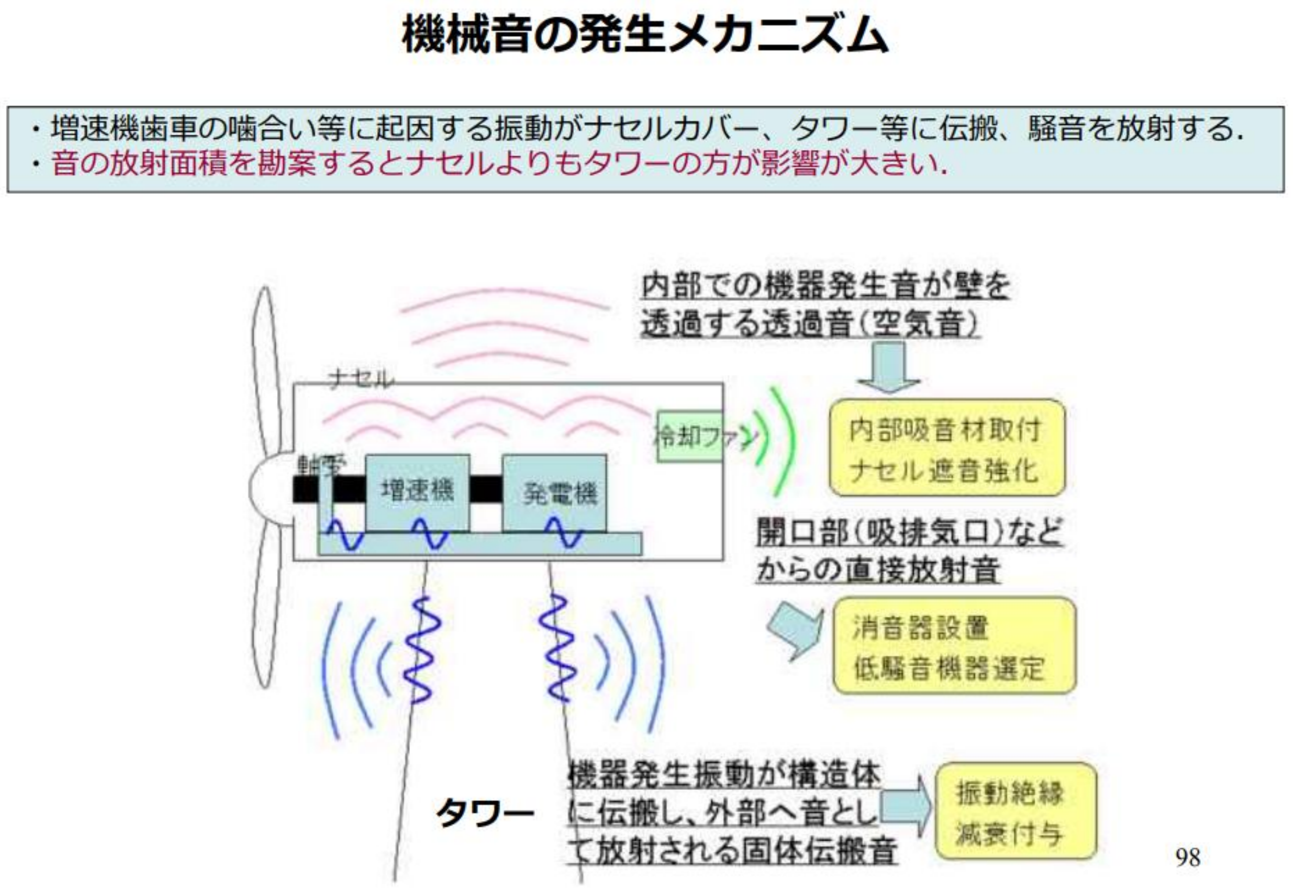
Table 3 shows the correspondence between the peak value of sound pressure and the frequency at that time.

ピーク値の周波数	倍率1	倍率2	音圧	0.816667の倍数			
0.266667	1		0.05604				
0.533333	1.999996		0.03093802				
0.816667	3.062497	1	0.1405225	0.816667	1	0.816667	
1.583333	5.937491	1.938774	0.0435531	1.633334	2	1.633334	2
2.416667	9.06249	2.959183	0.02416667	2.450001	3		
3.216667	12.06249	3.938774	0.03173804			3.266668	4
4.000000	14.99998	4.897957	0.01772484	4.083335	5		
4.866667	18.24998	5.959182	0.01728335			4.900002	6
5.466667	20.49998	6.693875	0.01009538	5.716669	7		
6.266667	23.49997	7.673467	0.00978232			6.533336	8
9.783333	36.68745	11.97959	0.03974005				

Table 3 Frequencies of the peak values

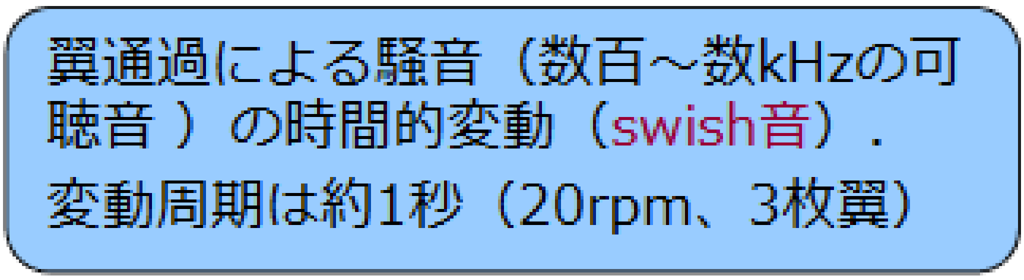
In ordinary science and physics, we often measure sounds that actually exist and consider the mechanism and characteristics of their generation. In the world of wind-turbine sounds, it seems customary to search the literature and discard anything that is not convenient.

For instance,
Date: Wednesday, October 31, 2018 13:30-15:00 Venue: Kumamoto Regional Joint Government Building (Building B) (2-10-1 Kasuga, Nishi-ku, Kumamoto City) IC Engineering Co., Ltd. Engineering Division Yasuo Inoue
In the illustration of the



It focuses on mechanical sounds, but does not touch on specific frequencies.
Although it is written that the influence of the tower is large, it does not describe what role the tower part plays and what kind of vibrational frequency components it has a deep relationship with.

Mr. Inoue also writes about "aerodynamic sounds".



It describes the temporal variation of noise from a few hundred to a few kHz, but does not describe the computational process that shows why aerodynamic sounds sound in such a frequency band.

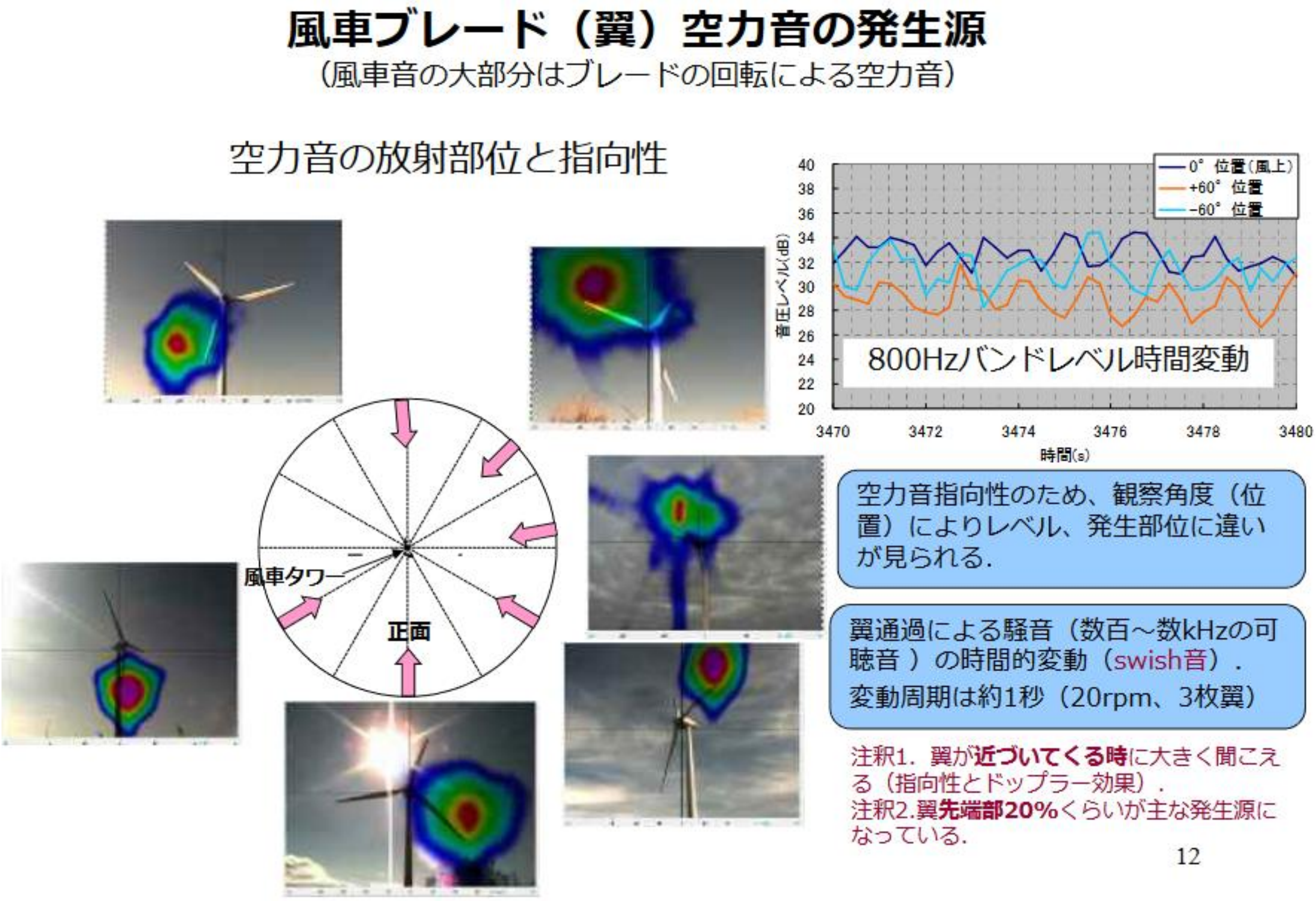
FFT calculations are reversible, so the recorded sounds are recorded as a record of fluctuations in the time domain. The results of the FFT conversion are displayed in the frequency domain. Then, you can extract only a few hundred or a few kHz components and convert them back to time-domain data with an inverse FFT.

If you look at the fluctuations in their amplitudes, you can see that the amplitudes of components from a few hundred to several kHz also fluctuate in time. However, the amplitude is only negligible compared to the amplitude of infrasound sound.

FFT can be used to decompose sound into 0~20Hz, 20Hz~100Hz, and 100Hz~20kHz components.

You should compare their amplitudes before you think about it.

High-frequency sounds are just the kind of sounds that you can just close the window on. The amplitude is also known.



The frequencies that can be measured by the acoustic camera used here are:

- 音響カメラは音響ビームフォーミング法という手法を用いている．
- これは騒音発生源から十分に離れた位置から音の発生源を可視化するものである．
- 多数のマイクロホン（カメラは48個）を用いて鋭い指向性 （方向性）を持たせることにより、どの方向のどの部位から　どのくらいの大きさの音が発生しているかを可視化することができる．

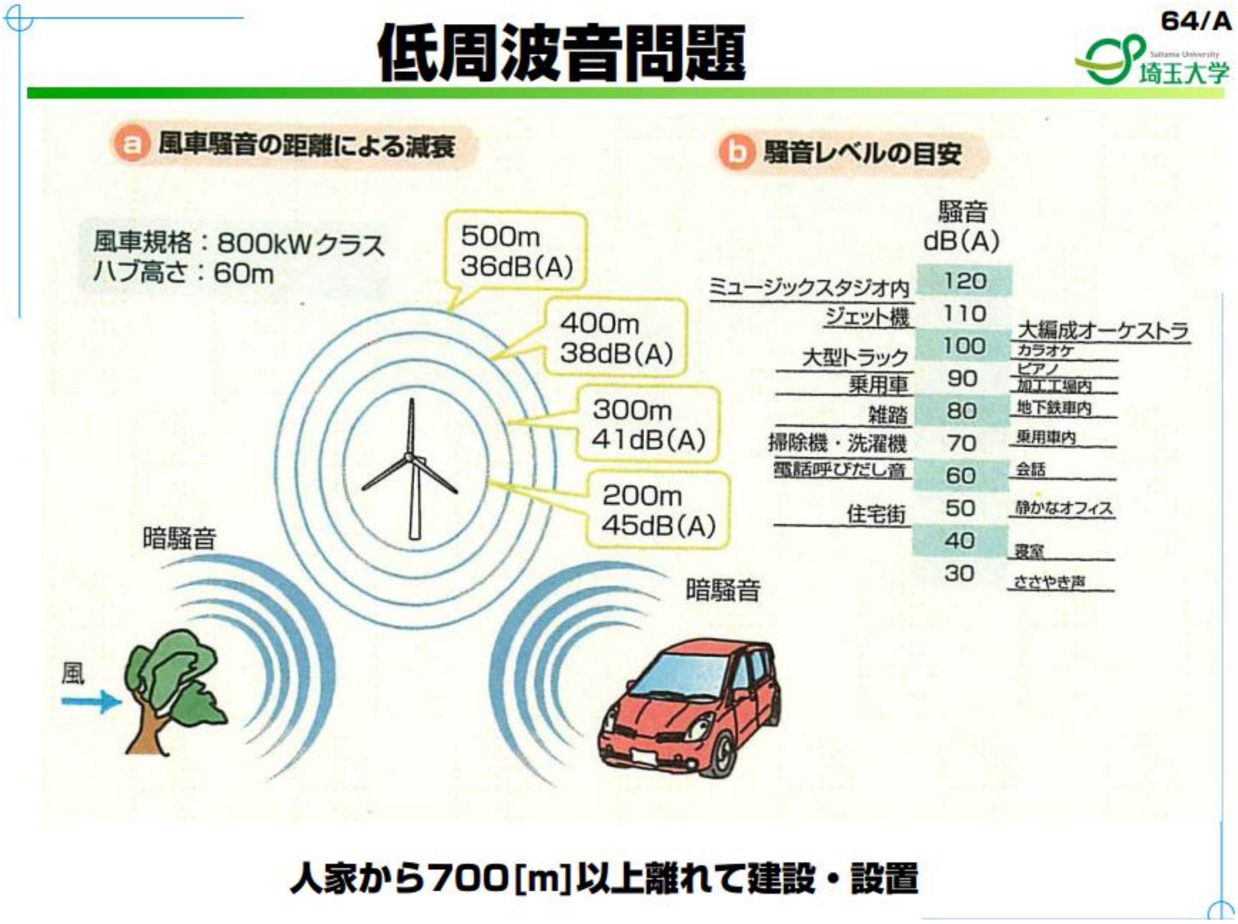
- 仕様 ： マイクロホンアレイ
- 型番 ： GFai Star48 Array
- 寸法 ： 最大スパン3.4m
- マイクロホン ： 1/4インチ48ch
- 適合測定距離 ： 3m-300m
- 適合周波数範囲 ： 100Hz-7kHz
- 画像処理 ： アレイ中心のカメラを用いて音響イメージと実画像の重ね合わせが可能

Since the compatible frequency range of this acoustic camera is 100Hz~7kHz, it is designed to handle only the part of the extremely low frequency sound that accounts for more than 93% of the energy of the wind-turbine sound.

It is natural that you cannot tell the difference between sound pressure fluctuations in components with high sound pressures around 0.5 Hz and amplitude modulation with components above 100 Hz. In the first place, the components of infrasound have not been measured.

Professor Hasegawa of Saitama University

Use the following diagram to illustrate the low-frequency sound problem.



The problem is that the title of the figure is "Low Frequency Sound Problem", but the detailed descriptions in the figure are "wind turbine noise" and "noise level". When you use noise, there is usually a limit to the frequency. Anything above 20 Hz is called noise.

Low-frequency sound is replaced by low-frequency noise. As a result, infrasound below 20 Hz is ignored. This leads to ignoring more than 93% of the energy of wind-turbine sound and proceeding with the discussion.

As a result, the comparison in the upper right corner of the figure ignores the characteristics of sound (e.g., energy distribution in each frequency band). The diagram of the wind-turbine also ignores the fact that the sound of the wind-turbine has a strong directionality.

It's a commentary that can only be said to be a pity.

The use of the term "noise" is described on page 22 of the "Response to Noise Generated by Wind Power Generation Facilities" (Report of the Study Group).

Note: Supplement on "Extremely Low Frequency Sound"

In Japan, the term "low-frequency sound" has been defined and used as "generally less than 100 Hz sound" based on the occurrence of complaints, but internationally, the frequency range of "low-frequency sound" varies from country to country and is not fixed. On the other hand, according to the IEC (International Electrotechnical Commission) standard 61400 series, 20 Hz or less is defined as "infrasound" and 20~100 Hz is defined as "low frequency noise", and in Japan, it is also defined in JIS C 1400-0:2005 (Wind turbine power generation system - Part 0: Wind power generation terminology). In light of this, the Ordinance of the competent ministry stipulated in the Environmental Impact Assessment Act as a technical guideline for each type of business defines "noise (including sounds with a frequency of up to 20~100Hz)" and "extremely low frequency sound (sound with a frequency of 20Hz or less)" and does not use the term "low-frequency sound". In light of these circumstances, in this report, sounds below 20 Hz are referred to as "infrasound sounds" and other sounds (including sounds with frequencies up to 20~100 Hz) are referred to as "noise."

In the report, infrasound is referred to as infrasound (0Hz~20Hz) and noise is referred to as noise (20Hz or more).
Also
"According to the IEC (International Electrotechnical Commission) standard 61400 series, 20 Hz or less is defined as "infrasound" and 20~100 Hz is defined as "low frequency noise."
As for the part, it is also written as infrasound (0Hz~20Hz).
For more information, see
The definition of "infrasound" in ISO7196 is:
3 Definitions
For the purpose of this International Standard. The following definitions apply.
3.1 infrasound: Sound of noise whose frequency spectrum lies mainly in the band from 1 Hz to 20 Hz.
It has become.
"Infrasound" is not defined as "1~20Hz sound waves", but as "sounds whose frequency spectrum mainly falls into the band of 1Hz to 20Hz".
By this definition, it is infrasound even if there is a frequency component that does not fit in the 1 Hz to 20 Hz band.
ISO7196 is also prepared for cases where it goes out of the 1 Hz to 20 Hz band.
In ISO7196, the center frequency in the 1/3 octave analysis ranges from 0.25 Hz to 315 Hz. Extremely low frequency sound in this sense will be written as infrasound (ISO7196).
Therefore, if you add noise, it will be more than 20 Hz. The difference between the title and the content is too large.

・ The old view of the Ministry of the Environment

A long time ago, the Ministry of the Environment said that the frequency of infrasound is

"4.1.5 Wind-turbine

The principle of generating infrasound in wind-turbines is basically similar to the so-called rotational sound of a blower. In the case of a large-scale wind turbine for power generation, the number of blades is small and the rotation speed is small, so extremely low-frequency sound may be generated even in normal operation.

The fundamental frequency f (Hz) is when the number of revolutions of the blades is R (rpm) and the number of blades is Z (sheets).

$f = RZ/60$ (Hz)

This fundamental frequency and its higher frequencies are preeminent. In the case of large-scale wind turbines for power generation, the number of blades is generally 1~3 (mainly 3), the rotation speed is about 30~60 (rpm), and the fundamental frequency is a few Hz or less. "

He said.

・ No infrasound is generated (Aritomo Nakano)

There is also the following theory by Mr. Nakano.

Dr. Aritomo Nakano, Director of the Nakano Environmental Clinic, states that "many low-frequency sound problems are misunderstanding problems" as follows.

6. Wind turbines do not emit low-frequency or infrasound-frequency rotational noise.

Many wind turbines for wind power generation have been installed throughout the country. Among them, there are places where problems are occurring, such as low-frequency sound emitted from wind-turbines and infinitesimal frequency sound, which has an adverse effect on the human body. And because this is reported on TV and other media, it is assumed to be true.

However, this is due to a misunderstanding of the most basic aspects of the generation of sound waves, which is completely false.

The wind-turbine does not emit the problematic ultra-low frequency and low-frequency rotation noise. It is the normal noise problem that can be problematic.

* Generated sound from generator

In addition to wind turbines, wind power generators consist of speed increasers, generators, substations, and the like. However, since all of these dimensions are sufficiently smaller than the wavelength of infrasound 17~340m, infrasound perceived from these does not generate infrasound perceived from them.

This is because when the dimensions of the vibrating object as the sound source are sufficiently small compared to the wavelength, the air on the surface of the object escapes to the side, so the air is not compressed and the generation of sound waves almost disappears.

The sound problem of wind power generation equipment is not a low-frequency sound problem or an infrasound problem, but a problem of ordinary mechanical noise.

・ Broadband sound and infrasound (ISO7196) (Central Research Institute of Electric Power Industry)

A Literature Survey on the Characteristics of Wind-turbine Sound and Its Effects on the Mind and Body: A Study Focusing on Low-Frequency Sound
Survey Report: N 10032 Report of the Central Research Institute of Electric Power Industry

in order to
Key Results
Characteristics and sound pressure levels of wind-turbine sounds, and the physical and mental effects of low-frequency and infrasound-frequency sounds
As a result of examining about 80 papers, the following findings were obtained.
1. Characteristics of wind-turbine sound
The main sources of wind-turbine sound are mechanical sounds inside the nacelles and aerodynamic sounds from the blades (Fig. 1).
The aerodynamic sound of the blades is a broadband sound, but the sound power is a power of the blade rotation speed.
Because of the proportionality (Figure 2), in large wind-turbines the mechanical noise from the blades is compared to the mechanical noise from inside the nacelle.
Aerodynamic sound becomes dominant. In addition, the aerodynamic sound generated by the wind-turbine blades is used to rotate the rotor
In total, it may fluctuate at a frequency of about 1 Hz, but this is because it is several hundred ~ thousands of Hz.
It is a sound that can be heard by periodically changing broadband sound in a relatively high range, and it is not an infrasound frequency.
2. Effects of infrasound from wind-turbines
The sound pressure level of infrasound from wind-turbines is generally perceptible in and around homes.
The value is well below the bell and does not appear to be audible (Figure 3). That's it.
Therefore, it is considered that the extremely low frequency sound from the wind-turbine is extremely unlikely to affect the mind and body.
3. Effects of low-frequency sound from wind-turbines
Depending on the size of the wind turbine, the distance from the wind turbine, and the air environment, low-frequency sound from the wind turbine may be perceived.
There is a possibility. In addition to the loudness of the wind-turbine sound, the receiver (difference in sound environment and subjective perception
It has been pointed out that if the conditions overlap, discomfort and sleep effects may occur.
It is not clear whether the direct cause is low-frequency sound. In addition, its sound pressure level is a direct
It is much smaller than the experimental value that examined the limit value for physiological damage.

Also

2.3 Evaluation method of infrasound

Infrasound is a sound wave of 1~20Hz defined in ISO7196 [2-20], and it is very difficult to hear and rarely perceived in daily life because it has a particularly low frequency among low-frequency sounds.

Regarding the part of "sound waves of 1~20Hz defined in the ISO7196 of infrasound frequency sound",
I checked the original text.

3 Definitions

For the purpose of this International Standard. The following definitions apply.

3.1 infrasound: Sound of noise whose frequency spectrum lies mainly in the band from 1 Hz to 20 Hz.

It has become.

It is not "sound waves of 1~20Hz", but "sounds whose frequency spectrum is mainly in the band of 1Hz to 20Hz"

It should be translated as: The center frequency at ISO7196 is 0.25~315Hz.

・ Karman vortex (backward turbulence) theory

Visualize invisible low frequencies. "Karman vortex" by wind-turbines visualized by snow;2014-02-21 | Wind power is dangerous

And now

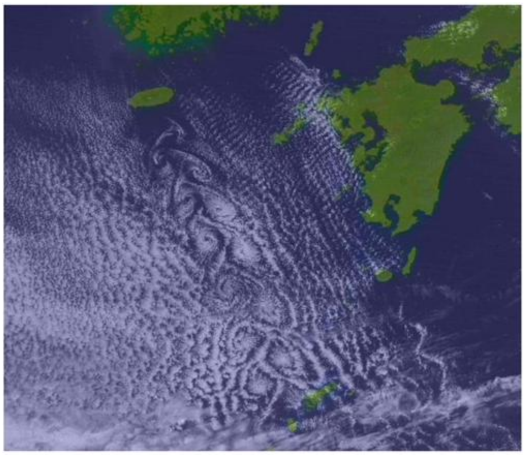
The low frequencies generated behind the pillars of the giant wind-turbine for wind power generation are beautifully reflected in the snow and lights as Karman vortices.

Turbulence occurs behind the support, and a sudden change in atmospheric pressure occurs, so it seems that just by approaching a bat, the blood vessels will burst in the lungs and the lungs will be filled with blood and die. This back turbulence results in low frequencies.

[Karman vortex]

A Karman vortex or Karman vortex sequence is a sequence of vortices that alternate behind when an obstacle is placed in the flow or when a solid is moved in a fluid. Named after the Hungarian fluid mechanic Theodore von Karman.

It has been proven in the meteorological world that obstacles protruding into the fluid can cause vibrations.

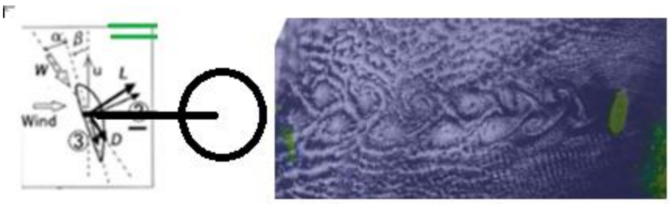


It was written.
In the above story, low frequencies are generated by backward turbulence.
However, it does not say how the frequency of low-frequency sound is determined.

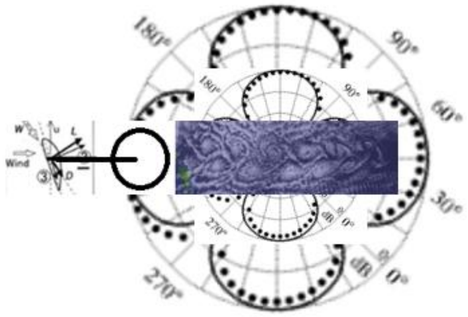
As we have seen before, wind conditions can change drastically. Even if the wind movement changes, does the Karman vortex move regularly and produce low-frequency sound with a stable frequency, or does the Karman vortex stabilize the frequency of the low-frequency sound produced by the Karman vortex for some reason, even if the Karman vortex is unstable?

To explain the stability of low-frequency sound from wind-turbines, we believe that Karman vortices are not suitable. There is a lot of research on Karman vortices, but I couldn't find anything that actually measured the sound from the wind-turbine and compared it with the data that calculated the frequency spectrum and sound pressure, or the results of the Wavelet analysis. To investigate the temporal stability of frequencies, a wavelet analysis is required.

Furthermore, in order to show that infrasound has a cross-shaped directionality centered on a wind-turbine, the source of the sound must be in a straight line that includes the wind-turbine.
The location of the Karman vortex is not on this straight line.
If we consider the tower and the Karman vortex, we get the figure below.



The location of the Karman vortex is behind the tower. The source of the sound is behind the tower, and when viewed from above, it is considered to have a symmetrical directionality about the axis of rotation of the wind-turbine.



Compared to the observation results, the position of the sound source and the direction of directivity are different.

In the vicinity of wind-turbines, infrasound is directional.

2) Yoshihiro Kikushima, Hisatoshi Nagashima, Shota Hashimoto, Masato Kujioka, Yukio Hamada, Hirokazu Kawabata, Tetsuya Ogaki, Effect of wind speed on wind turbine noise directionality, according to Symposium on Wind Energy Utilization Vol.38, p. 69-72, 2016

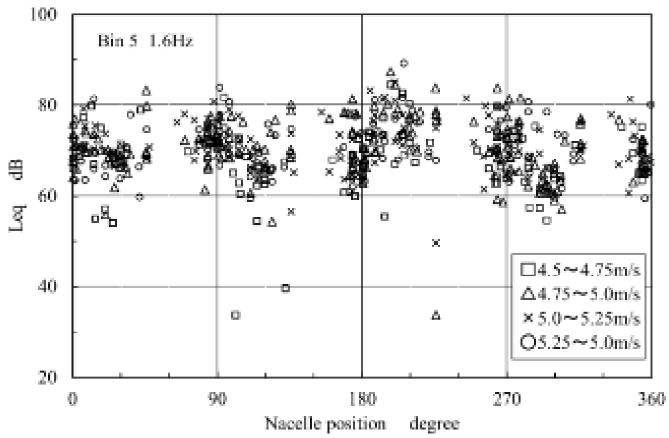
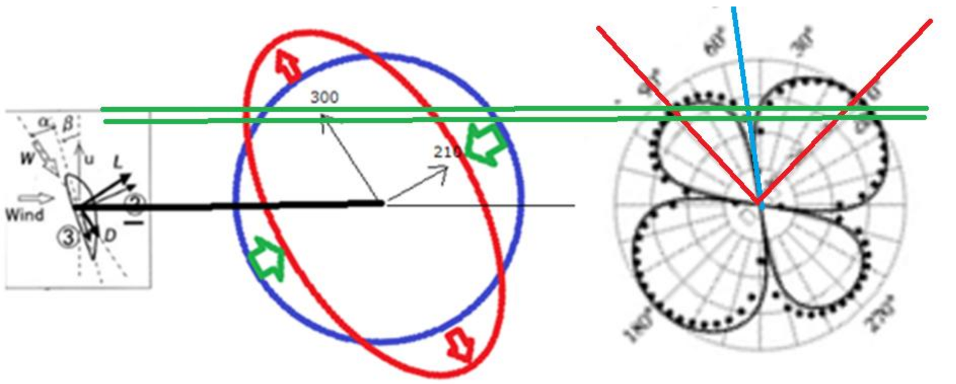


図 6 Bin 5 中心周波数 1.6Hz の指向性分布

If we illustrate the relationship with the rotation axis of the wind-turbine, it will be as follows.



It is in the direction of (210+90*k) degrees that it becomes stronger.

・ **Aerodynamic modulation theory**

A Study on Noise Prediction and Evaluation Methods for Wind Power Plants Akihiro Suzuki

8. Low-frequency Boeing, ultra-low-frequency Boeing

There are reports that make us suspect that strong "low-frequency sound" is being generated from wind-turbines. Japan's Ministry of the Environment defines low-frequency sound as "low-frequency audible sound of approximately 100 Hz or less" and "extremely low-frequency sound" (Appendix 7).

In wind turbines with a rated output of 2 MW, which have become mainstream in recent years, the rated rotor speed is about 20 [1/min]. In the case of a three-bladed rotor, for example, the blades pass through the front of the tower 60 times per minute during rated operation, so a fluctuation of sound occurs once per second. Therefore, it is argued that this is the source of infrasound at 1 Hz, but this is due to amplitude modulation of audible broadband aerodynamic sound generated by wings.

Be. It **is called aerodynamic modulation (Appendix 8), and is basically a state in which the sound pressure level (volume) of a sound containing a wide range of frequency components (including extremely low frequency sound components) rises and falls at a rate of once per second, and is a phenomenon different from infrasound sound, which is an air vibration with a frequency of 1 Hz.**

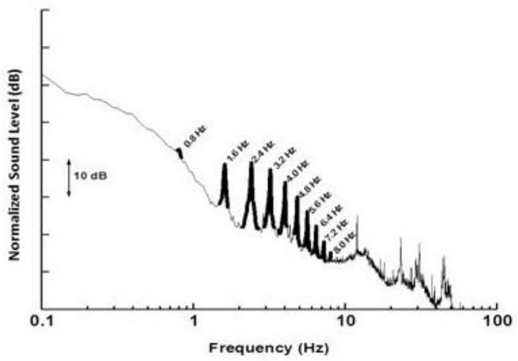
According to the results of surveys conducted by government agencies overseas, the (ultra-)low-frequency sound generated by wind turbines is at a low level (see Appendix 9), and the problem is considered to be the variable audible sound.

Measurement results in Canada show that:

A Primer on Noise

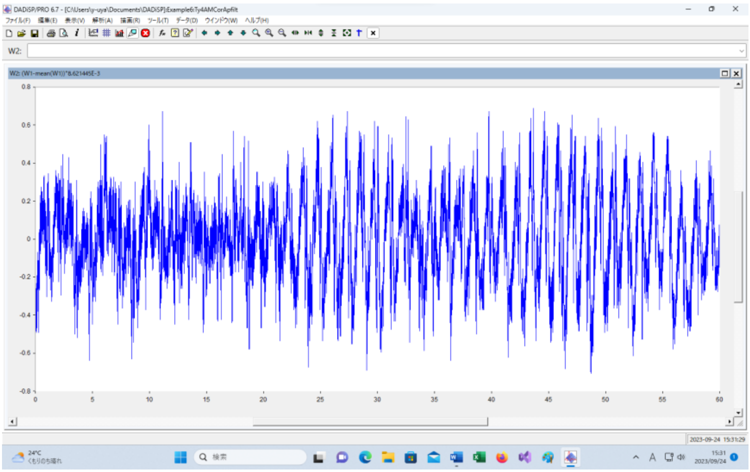
The frequency of rotation of a source can be used to help identify the source that is producing the sound. For example, a wind turbine with 3 blades, spinning at 16 revolutions (full rotations) per minute (RPM) will have a fundamental frequency that corresponds to 0.8 Hz (i.e. (3 blades X 16 RPM) divided by 60 seconds). Therefore, in this example, one can isolate the wind turbine sound from background noise if in the measured sound at a given distance, **the sound level due to the wind turbine is high enough to show frequency peaks at the fundamental frequency and at multiples of the fundamental frequency. These multiples are called harmonics and for a source with a 0.8Hz fundamental frequency, they would be 1.6 Hz, 2.4 Hz, 3.2 Hz, 4.0 Hz, 4.8 Hz, and so on.**

▸ Figure 2: Wind Turbine infrasound Measurements



と It is becoming.

The graph of wind-turbine sounds is as follows:



The sound of the wind-turbine is divided into components of 0~20Hz for blue, 20~200Hz for green, and 200~24kHz for red.

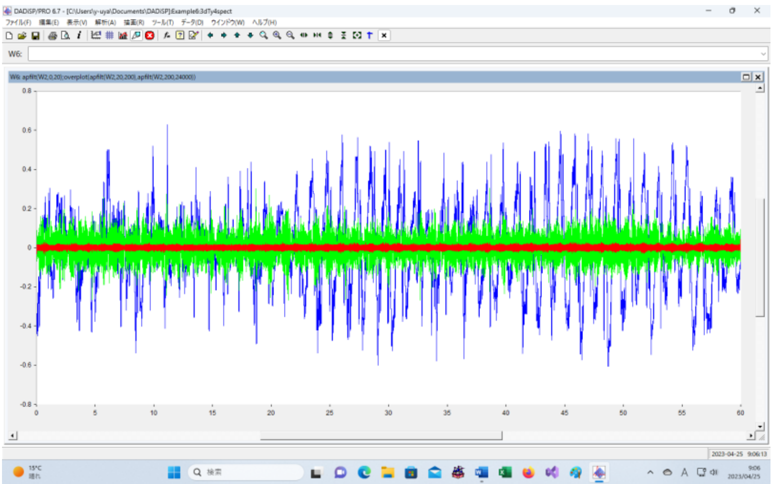


Fig.5 Separated Wind turbine noise

・ The sound of cutting the wind

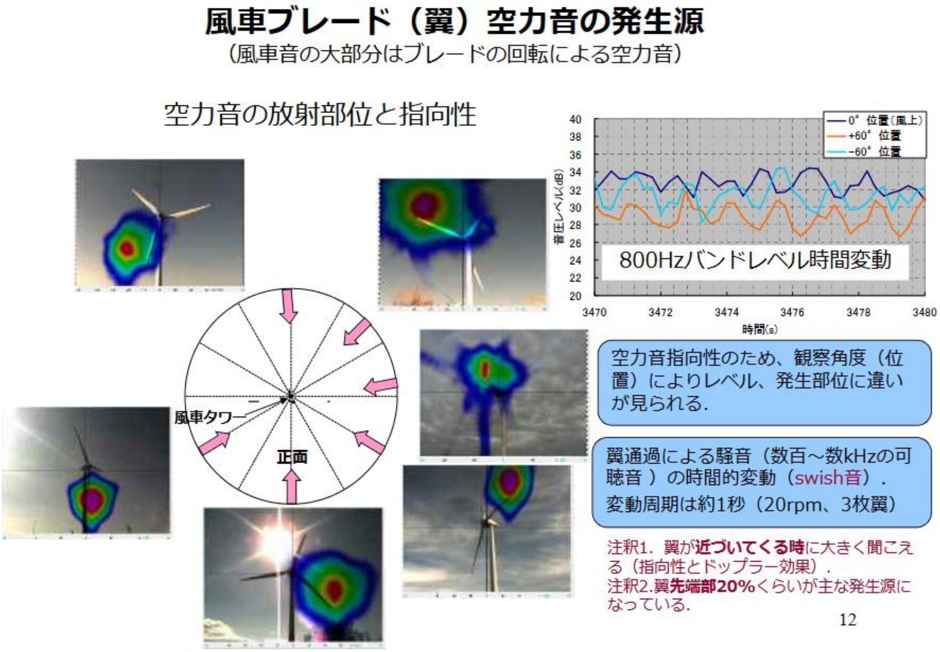
As for the sound of cutting the wind, I was told as follows.

Mr. Yasumasa Uyama
Thank you for your question email.
If the wind noise of the wind-turbine is the rotation speed R of the blades (number of revolutions per minute: R-rpm) and the number of blades N, the fundamental frequency f from the wind turbine is indicated by $f = N \times R/60$. This equation is the number of revolutions of an uncovered fan, supported by a strut, the number of blades, and the fundamental frequency f generated there.
In Higashi-Izu, where 1,500 kW-class wind-turbines line the ridge of the mountain, they rotate 20 times per minute when the wind blows strongly, and the wind turbine in the middle of the three wind turbines that stood along the Ishikari spillway that carried water from Ibarado in Ishikari City, Hokkaido was almost the same standard.
Since it is 20 rpm with three blades, it will pass by the strut 60 times in 1 minute, and the wing will pass once in 1 second, so $f = 3\times20/60 = 1$ Hz.
When the wing rotates, it causes a large pulse-like sound pressure fluctuation with a time width when the air flow (wind) is torn between it and the strut.
This state is measured with a measuring instrument and frequency analysis (FFT analysis) shows that it consists of 1 Hz and its overtones.
The sound from the wind-turbine is the sound of the acceleration gear system (which moves to change the power frequency to several tens of times) in the nacelle, the sound of the motor to change the direction according to the wind direction, the sound of the motor to change the angle of the wings, the sound of the fan for cooling in the nacelle, etc.
Still, the loudest is the sound of the wings spinning, which converts wind energy into electricity.
If you actually measure the sound of a wind-turbine at a distance of several tens of meters, you can hear the sound when the wings swing down.
The tick-tock sound of the wall clock every second is also sounding every second, but the analysis with the measuring instrument does not show the basic sound.
This seems to be due to the small range of pulsed sounds of tick-tock.
This can be seen from the fact that when the length of the ON and OFF time of the square wave signal changes, the size of the composition of the fundamental tone and its odd multiples of overtones changes.
Although it is not very helpful Japan, the above equation is written on page 24 of the Acoustical Engineering Course 5: Noise and Vibration (below), edited by the Acoustical Society of Japan, as the frequencies of the blades passing from the blower.

Wind noise
"When the wing rotates, it causes a large pulse of sound pressure fluctuations with a time width when it tears the air flow (wind) between it and the struts."
In this case, the speed of the tip is the maximum for the long wing, and the speed of the wing decreases as it moves

toward the center. At this time, the flow of air that is torn between the pillars and the column changes continuously, so the frequency spectrum of the sound is considered to change continuously. The measurement results are discrete frequencies.

"When the wing rotates, it causes a large pulse of sound pressure fluctuation with a time width when it tears the air flow (wind) between it and the strut."



The color of the blades when they pass in front of the tower and the size of the red part have not changed much.
There is no sudden fluctuation in sound pressure around 800 Hz.
Therefore.　I don't think there is a phenomenon that can be said to be "tearing the air flow (wind) between the wing and the support when it rotates".

It's not just the overtones that actually come out.
f=RZ/60 [Hz], and frequencies of f/3, 2f/3, f, 2f, 3f、...、 8f [Hz] are also produced.
Of these, it is necessary to explain that f/3 and 2f/3 [Hz] sounds are emitted.

The wind-turbine sound has a cross-shaped directionality. The area where the air flow is torn off is considered to be linear, but this does not create a cross-shaped directionality. In order to create a cross-shaped directionality, four sound sources are considered, and their movements are harmonious and the movement is the same frequency, making it possible to have the directivity of the wind-turbine sound.

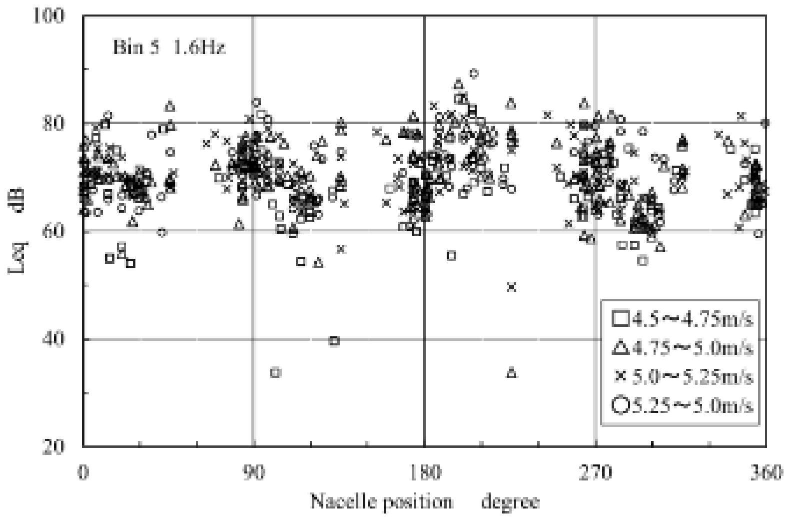
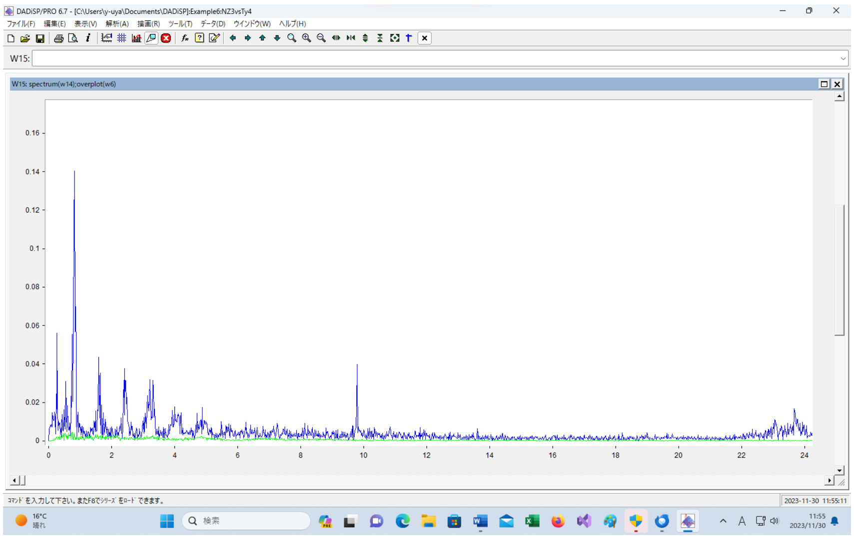


図 6　Bin 5 中心周波数 1.6Hz の指向性分布

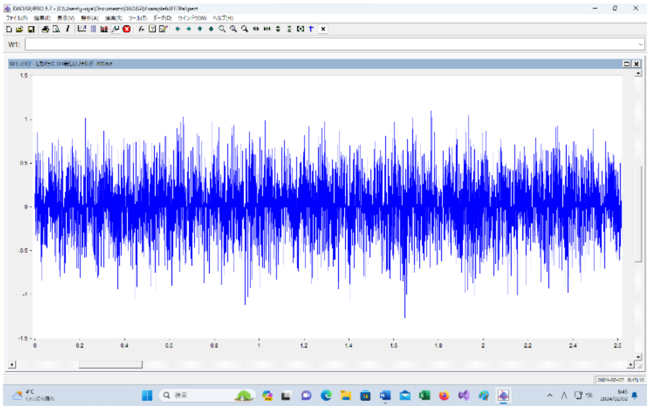
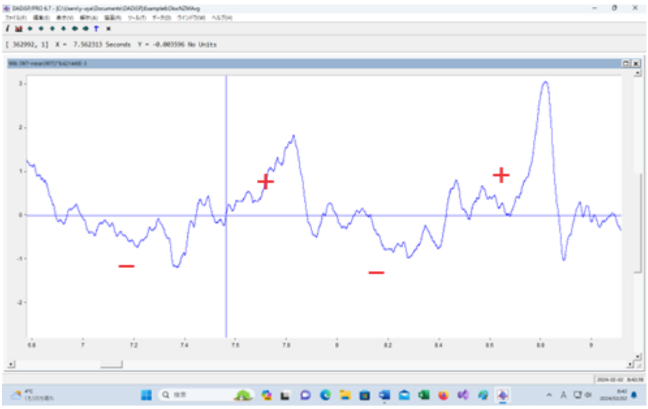
In addition, it is necessary to explain whether the angle seen from the axis of rotation of the wind turbine is this angle.

"When the wing rotates, it causes a large pulse of sound pressure fluctuations with a time width when it tears the air flow (wind) between it and the struts."

In this case, the speed of the tip is the maximum for the long wing, and the speed of the wing decreases as it moves toward the center. At this time, the flow of air that is torn between the pillars and the column changes continuously, so the frequency spectrum of the sound is considered to change continuously. The measurement results are discrete frequencies.



2.6 seconds waveform of factory noise 2.2 seconds waveform of wind-turbine sound

If you look at the graph on the right, you can see that it is not pulsed. Because the sampling rate is low, it looks pulsed.

In addition, it is necessary to reconcile the characteristics of frequencies in the region of infrasound and the description of directivity.

In the case of wind noise or aerodynamic sound, it is difficult to explain why the sound at the frequencies of 0.2667 Hz and 0.5333 Hz in the table above is generated. Of course, it is also difficult to explain the directivity of wind-turbine sounds.

・ Wind noise (Part 1)

Some people seem to think that the part of the infrasound that is below 5 Hz is "wind noise". If you think about it this way, you can blame the wind for the high sound pressure in the infrasound region.

"I think Mr. Uyama was considering the measurement of low-frequency sound from wind-turbines.

I think I have talked before about the fact that with the rotation of a wind-turbine, a component with a fundamental frequency of 60 blade÷s × 1 minute and a harmonic component (for example, 1 Hz and twice the frequency of a three-bladed wind-turbine with a rotation speed of 20 rpm) are generated.

However, the low-frequency sound observed at the site is the sound from the wind turbine superimposed on the wind noise.

Wind noise in the low frequency range is caused by wind hitting the microphone.

This noise has a larger component as the frequency decreases.

Low-frequency sound measurements are usually made in the absence of wind to avoid the effects of wind noise.

However, wind-turbines do not turn without wind, so they are affected by the wind.

In mountainous areas and areas where the wind is blocked by ridges that are less susceptible to wind, the component associated with the rotation of the wind turbine is observed as a preeminent component in the frequency analysis results.

On the other hand, in the measurement results of places that are easily affected by wind, such as flat ground, the frequency characteristics in the low frequency range are dense and raised, and the outstanding components are often not observed. This is considered to be due to the predominance of wind noise over wind-turbine noise.

Even if a windbreak screen with a diameter of about 20 cm, which is larger than a normal windbreak screen, is attached to the microphone, it will not be able to sufficiently remove wind noise when the wind is strong.
Various studies have been conducted on the reduction of wind noise, but it is currently difficult to remove wind noise in the frequency range of about 5 Hz or less (or about 10 Hz or less in some cases).
Therefore, one of the major challenges in accurately measuring low-frequency sound from wind turbines is how to eliminate the influence of wind noise.
I would be grateful if you could refer to this area in your research. ”

I was instructed, but I don't agree.

There are two meanings of "wind noise".
1, The sound generated by the wind hitting the microphone.
2, Infrasound in the frequency range below 5 Hz (in some cases approximately 10 Hz or less).

well
"Wind noise in the low frequency range is caused by wind hitting the microphone.
This noise has a larger component as the frequency decreases. “
However, when I actually measured it,
In the immediate vicinity of the wind-turbine, infrasound with high sound pressure and regular frequencies was measured, even when the wind did not hit the microphone.
When the sound level meter was placed in a plastic bag, placed in a cardboard box, loaded into the car, and the car door was closed, the sound pressure was higher than in other cases, although the frequency was the same.
This infrasound is not caused by the wind hitting the microphone. In the first place, the wind is not hitting the microphone.
In the vicinity of wind-turbines,
If we compare the results when the wind does not hit the microphone and the results when the wind hits the microphone, we can observe both infrasound sounds with high sound pressure and regular frequencies, but the wind does not cause a component of a different frequency to appear. Whether the wind hits the microphone or not, it will be recorded.
In the reflection of sound, the sound pressure is highest when you put it in a bag, put it in a box, and close the car door.
This means that reflections can occur indoors, and the sound pressure can be more than twice as high as the sound pressure outside.
Also
"In the frequency range below 5 Hz (sometimes around 10 Hz or less), wind noise is difficult to remove."
There is,
Since this component exists even if the wind does not hit the microphone, there is no need to remove it as "wind noise generated by wind hitting the microphone".
Without a wind-turbine, even if the wind is applied to the microphone, infrasound with high sound pressure and regular frequencies will not be measured.
In places where there are no wind-turbines, infrasound sounds with low sound pressure and no frequency regularity are

measured.

Therefore, it should be considered that the extremely low frequency sound generated by the wind-turbine itself is being measured. It's a sound that shouldn't be removed.

If you are a researcher about "wind noise",

"As you know, the measurement of infrasound is susceptible to the effects of wind, which is difficult to eliminate.

This is also stated in the Ministry of the Environment

's Guidebook for Dealing with Low-Frequency Sound Problems (H16.6)

and the Manual on Measurement Methods for Low-Frequency Sound (H12.10).

In addition, the measurement frequency range of the low-frequency sound level meter (Lion NA-18A) used for measurement at that time is 1 Hz or more.

Based on these, in the paper you pointed out, we have announced a 1/3 octave band of 1 Hz or more as the target frequency.

Based on the above, the frequency range is set to 1 Hz or more in consideration of the reliability of the data. ”

He said.

Extremely low frequency sound measured near wind-turbines can never be eliminated. It's not the effect of the wind, it's the infrasound from the wind-turbine.

This means that if you record the sound from the wind-turbine with the NL-62 and calculate the frequency spectrum from the data for 120 seconds, you can see that infrasound is measured.

near the wind-turbine, with a windbreak screen with a diameter of 9 cm,

Measure by making sure that the sound level meter is not exposed to the wind.

Measure while blowing the wind on the sound level meter.

If you compare the data obtained in such cases, you can immediately see whether it is due to the wind or not.

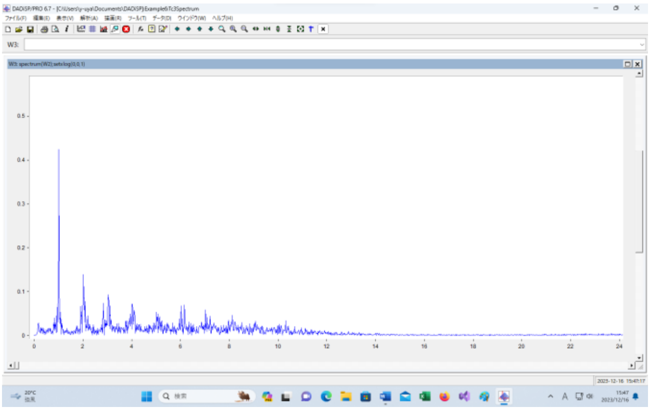
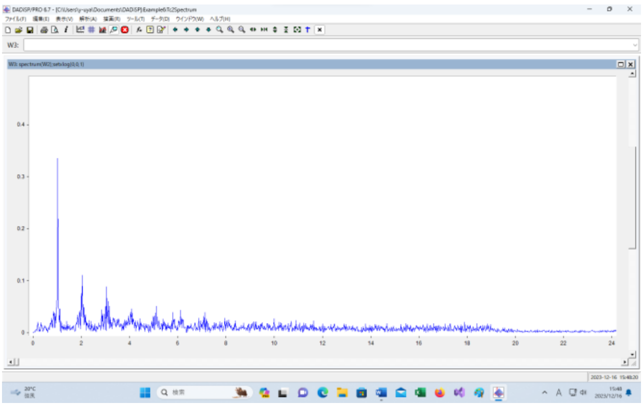
If you just want to avoid the effects of the wind, you can remove the influence of the wind by placing the measuring equipment in the car and opening the downwind window to measure. Of course, infrasound is recorded properly.

In the vicinity of wind-turbines, infrasound with high sound pressure is measured even if the wind does not hit the microphone.

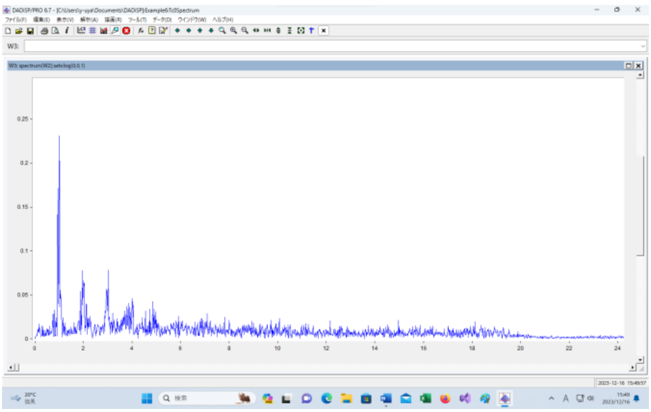
Measurement near a wind-turbine

Put the sound level meter in a plastic bag, put it in a cardboard box, cover it with vinyl,


In the bag and box, when the door is closed, Max. 0.42Pa when in the bag and box, and when the door is opened, Max. 0.33Pa

The result of taking it out of the bag and placing it on top of the box is Max. 0.23Pa



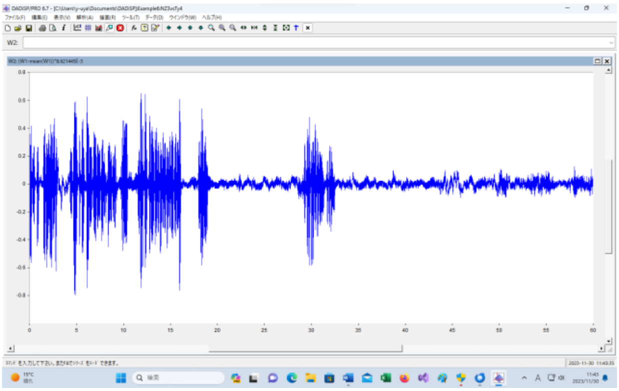
When it comes to differences in sound pressure, sound reflection must be taken into account.
If a wind-turbine is nearby, infrasound with high sound pressure and regular frequencies can be observed when the wind hits the microphone compared to when the wind hits the microphone.
The measurement results are available on the website. "Wind noise? (Tateyama) download (WAV)".

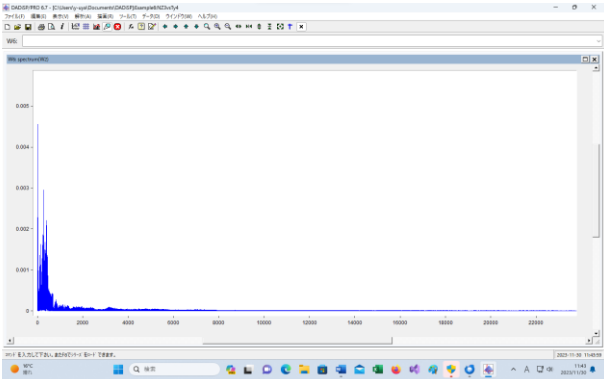
If there were no wind-turbines, the microphone would not produce high-pressure infrasound at high infrasound pressure.

In a place where there is no wind-turbine, if you measure by blowing the wind through a microphone, infrasound sound with low sound pressure and no frequency regularity will be measured. In places where there are wind-turbines, infrasound sounds with high sound pressure and regular frequencies are measured.

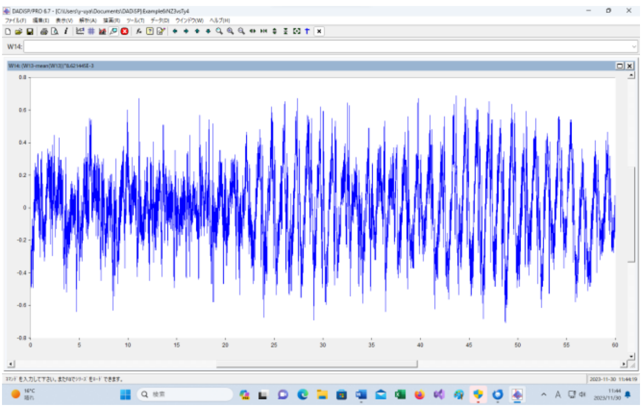
In places where there are no wind-turbines, the "wind noise" caused by the wind hitting the microphone has a low sound pressure and no regularity in the frequency in the infrasound range.
I measured it while blowing the wind on the microphone in the precincts of a nearby shrine. The result is:

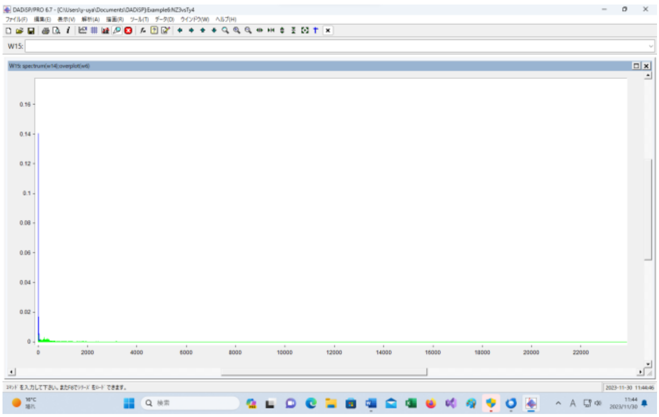
On the left is the sound at the shrine and on the right is the frequency spectrum of the sound at the shrine





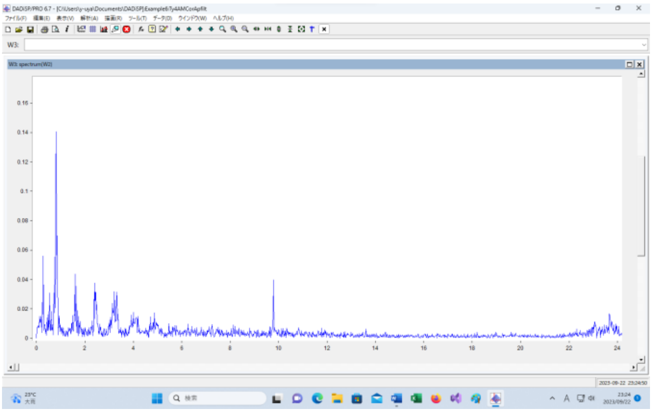
On the left is the sound of wind-turbines, and on the right is the frequency spectrum of the sound of wind-turbines (blue) and the sound of shrines (green).

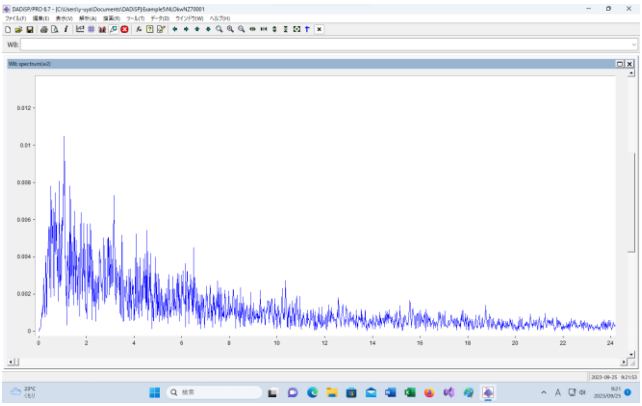




On the left is the sound near the wind-turbine, and on the right is the infrasound part of the sound recorded by blowing the wind into the microphone in a place where there is no wind-turbine.
In the following graph, we compare the sound of wind-turbines with the sound of the nearby Nagao Shrine in the range of 0~25Hz.

Sound near the wind-turbine (0~25Hz) Max. 0.14[Pa] (0.8Hz) Nagao Shrine (0~25Hz) Max. 0.0105[Pa] (1.1Hz)

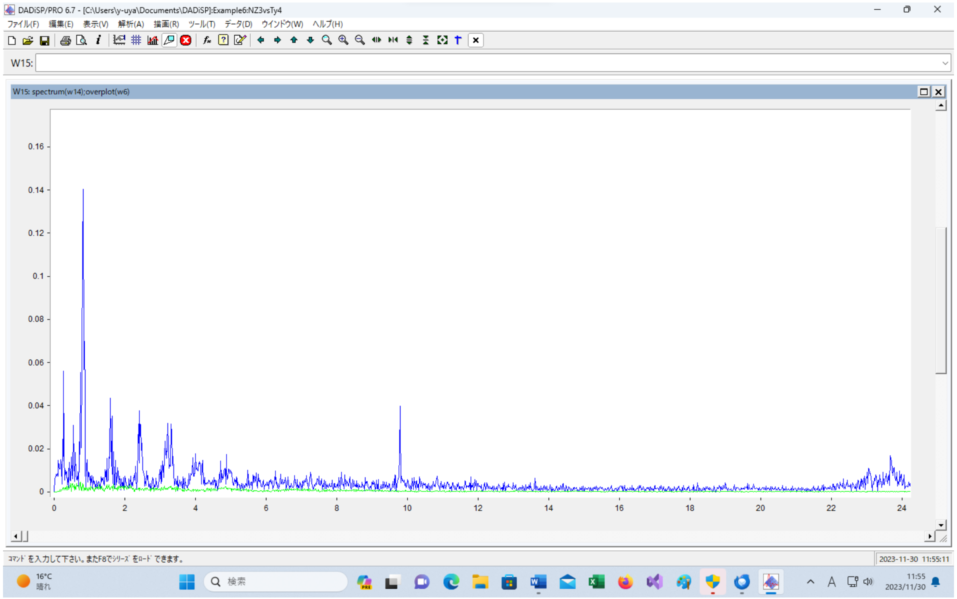




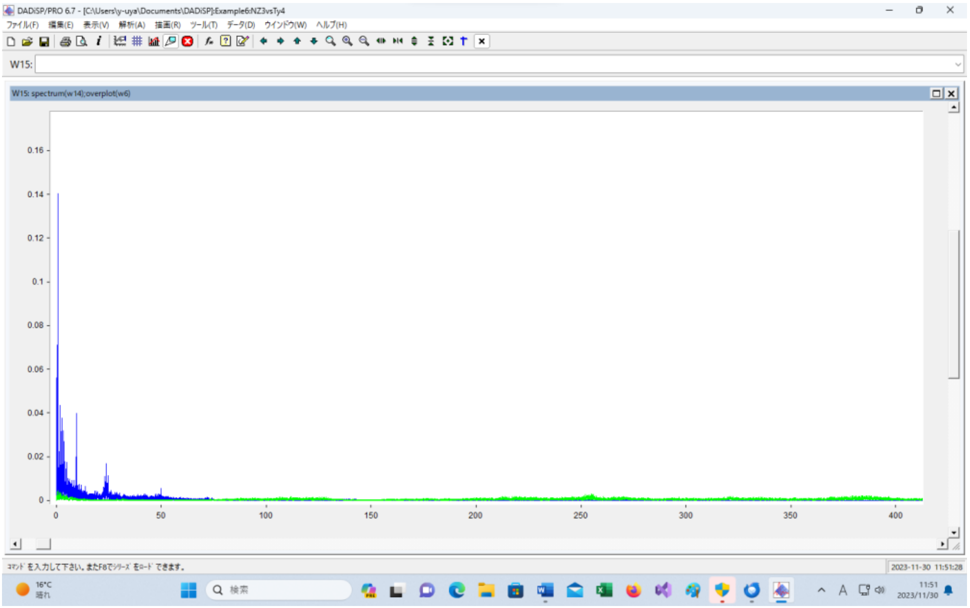
This is a comparison of the maximum sound pressure of 0.14 [Pa] (0.8 Hz), which is measured in the 0~25 Hz range by placing equipment in the car near the wind turbine and opening the leeward window, and the maximum sound pressure of 0.0105 [Pa] (1.1 Hz), which is measured with the microphone placed on the stairs of the shrine and exposed to the wind.
There is an infrasound frequency sound with a sound pressure of 0.14 Pa near the wind-turbine and 0.01 Pa in the absence of the wind-turbine. So, near the wind-turbine the sound pressure is 10 times. The sound pressure varies with the speed of the wind. There are times when it is 0.37 Pa near the wind-turbine and 0.003 Pa where there is no wind-turbine. With this, the sound pressure is 100 times.

In the following graph, the blue line is the infrasound near the wind-turbine, and the green line is the infrasound at the place where there is no wind-turbine.

Enlarged view from 0~24Hz, frequency spectrum of wind-turbine sound (blue) and shrine sound (green)



Enlarged view from 0~400Hz, frequency spectrum of wind-turbine sound (blue) and sound at shrine (green)



There are two types of "wind noise": one with high sound pressure and regular frequency near a wind turbine, and one with low sound pressure and no frequency regularity in a place without a wind turbine, and it is necessary to distinguish between these two types of "wind noise".

Sounds with clear regularities in frequency should not be dismissed as "wind noise". You have to be clear about why you have a regularity. If we investigate why wind-turbines produce such regular sounds, it becomes clear that the term "wind noise" is inappropriate. If the mechanism of generation is clarified, it will be understood that this sound should be called "infrasound from a wind-turbine ".

"Wind noise near a wind-turbine " has a special structure and is closely related to the rotation of the wind-turbine. This is the infrasound from a wind-turbine.

If we are talking about wind noise, we need to explain why the nature of wind noise is different near wind-turbines and in places without wind-turbines. It is impossible to say that 10Hz or less is wind noise.

"Wind noise: Noise caused by wind hitting a microphone."

I would like to summarize the reasons why the Ministry of the Environment and academics who insist on this cannot show a precise frequency spectrum.

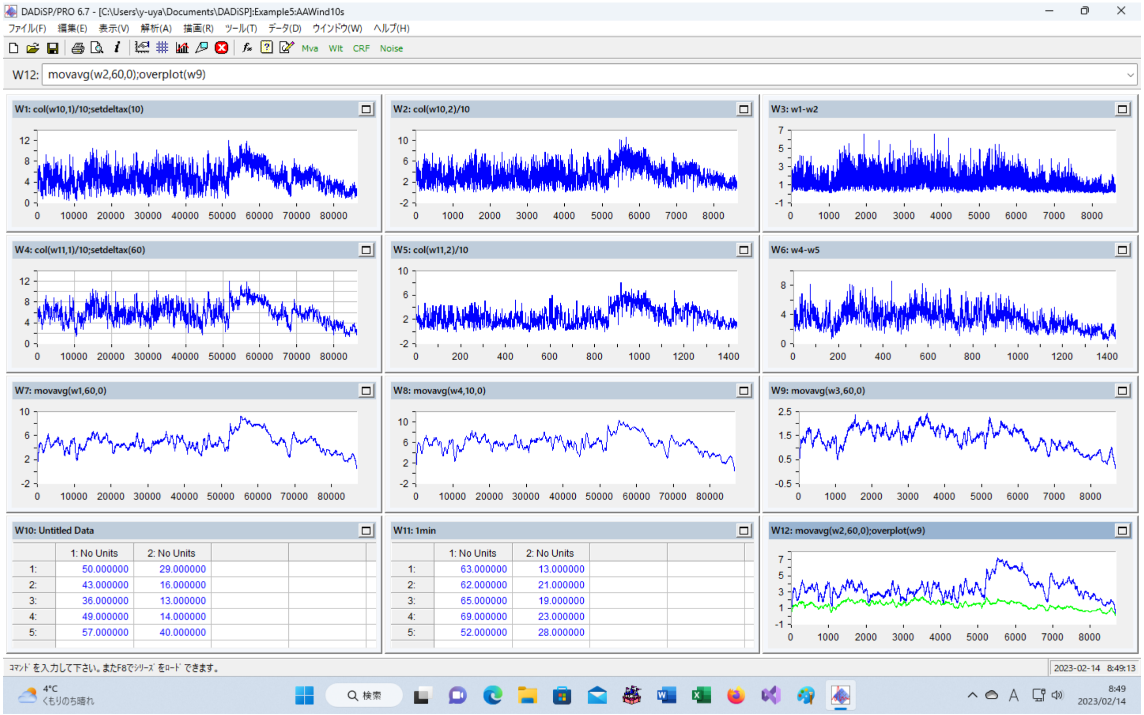
Wind changes direction and speed. The following table shows data measured by the Japan Meteorological Agency and obtained from the Japan Meteorological Business Support Center.

年	月	日	時	分	秒	前10秒間最大瞬間風速	前10秒間最小瞬間風速	前10秒間風程
						0.1m/s	0.1m/s	
2019	2	2	0	12	40	147	124	132
2019	2	2	0	12	50	146	107	131
2019	2	2	0	13	0	122	82	102
2019	2	2	0	13	10	105	65	83
2019	2	2	0	13	20	112	71	82

(The wind speed for the previous 10 seconds refers to the journey of the wind in 10 seconds.) 132 is a wind speed of 13.2 m per second. ）

Both the wind speed and direction are unstable.

The graph of fluctuations in wind strength is as follows.

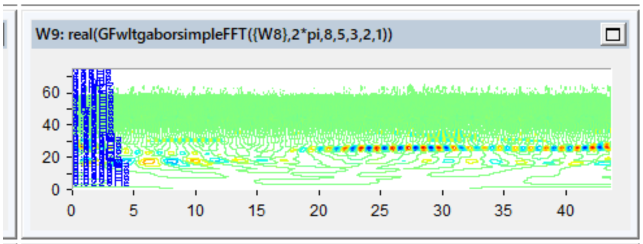


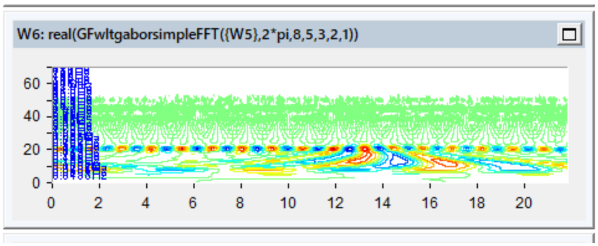
(The graph above is a 24-hour record for January 1, 2019.) ）

W1 (upper left) is the value of the maximum instantaneous wind speed for the previous 10 seconds (every 10 seconds), w2 (upper center) is the value of the minimum instantaneous wind speed (every 10 seconds) for the previous 10 seconds, W4 (left of the second stage) is the value of the maximum instantaneous wind speed (moving average for 3 seconds)

(every 1 minute),
w5 (center of the second stage) is the value of the minimum instantaneous wind speed (3-second moving average) (every 1 minute),
Are.

If the wind speed and direction change finely, the pressure when the wind hits the microphone will also change finely. If the strength of the wind hitting the microphone does not change at a certain period, the frequency of the data recorded by the wind noise should fluctuate.
However, the frequency spectrum of wind noise recorded per meter above the ground does not reflect fluctuations in wind pressure relative to finely varying microphones.
 If you examine the frequency spectrum of "wind noise" recorded near the wind turbine, you can see that the frequency at which the maximum sound pressure is f=RZ/60 (Hz). We can only assume that the wind hitting the microphone is a period corresponding to the rotation of the wind-turbine, and that the pressure on the microphone fluctuates.
In addition, even if the wind speed changes, the frequency of the wind noise will also change in response to the rotation of the wind turbine. The wind precisely changes the pressure applied to the microphone as the rotation of the wind-turbine changes.
The following graph shows the changes in frequency and sound pressure.





It can be seen that the frequency component of about 0.8 Hz is emitted at a strength of about 0.3 Pascals for about 100 seconds. It is long enough to generate resonance, resonance phenomena, etc., and wake up a sleeping person.
The relatively dark color indicates that the sound around 0.8Hz is strong.
If this line goes up, it means that the frequency is higher, and if it goes down, it means that the frequency is lower. A darker color means louder sound. Light color means that the sound is small.
The frequency is quite stable.
If it is wind noise, it is necessary to explain why it is possible to accurately change the pressure on the microphone at a distance of 1 m above the ground according to the rotation of the wind-turbine.
Changes in wind speed and

年	月	日	時	分	秒	前10秒間最大瞬間風速	前10秒間最小瞬間風速	前10秒間風程
						0.1m/s	0.1m/s	
2019	2	2	0	12	40	147	124	132
2019	2	2	0	12	50	146	107	131
2019	2	2	0	13	0	122	82	102
2019	2	2	0	13	10	105	65	83
2019	2	2	0	13	20	112	71	82

(The wind speed for the previous 10 seconds refers to the journey of the wind in 10 seconds.) 132 is a wind speed of 13.2 m per second. ）

Both the wind speed and direction are unstable. The change in wind speed does not match the stability of the frequency. Of course, the frequency changes slightly depending on the rotation speed, and the pressure applied to the microphone must be adjusted according to this change.

This is not determined by simply the wind speed. The orientation of the blades is also relevant. How does the wind know the speed of the wind-turbine and how does it adjust the pressure applied to the microphone? The only thing that can do this is "Wind God". The wind noise theory cannot be established without acknowledging the existence of the wind god.

Furthermore, if the Ministry of the Environment insists on the "wind noise" theory, it needs to explain why the frequency of "wind noise" has a harmonic structure. The sound pressure of the harmonics is determined by the coefficient of the McLaughlin expansion.

McLoughlin Deployment

$$（1(1+x)^{\alpha} = 1 + \frac{\alpha}{1!}x + \frac{\alpha(\alpha-1)}{2!}x^2 + \frac{\alpha(\alpha-1)(\alpha-2)}{3!}x^3 + \cdots 0）$$

The wind must also have the ability to respond accurately. It is truly a divine act.

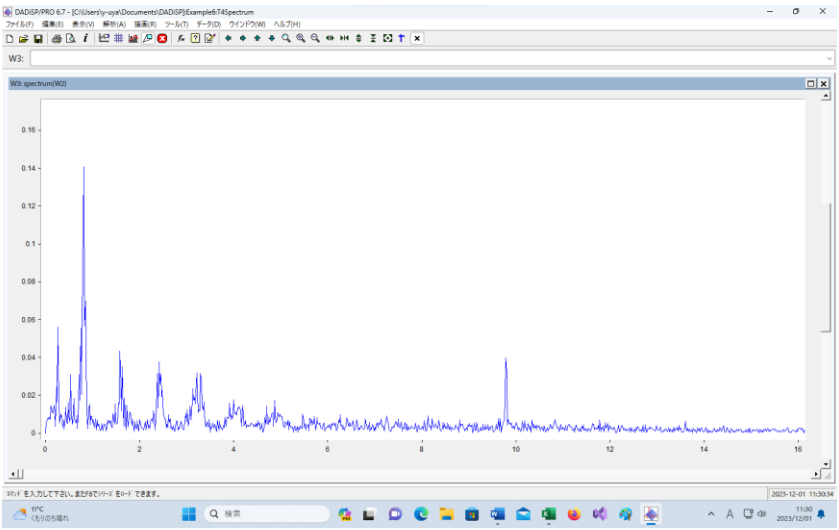


図.3 Wind turbine noise (0～25Hz)

The frequency at which the sound pressure reaches its peak value has the following regularities.

周波数	周波数/0.8167	音圧[Pa]
0.2667	0.3266	0.0560
0.5333	0.6530	0.0309
0.8167	1.0000	0.1405
1.5833	1.9387	0.0436
2.4167	2.9591	0.0377
3.2167	3.9387	0.0317
4.0000	4.8978	0.0177
4.8667	5.9590	0.0173
5.4667	6.6936	0.0101
6.2667	7.6732	0.0098

These realities are proof that the "wind noise" theory is false. The Ministry of the Environment, which does not want to admit this, forbids detailed frequency examinations. It can be measured outdoors with a double windproof screen, and if it remains in the data, it should be treated as an exclusion sound.
If the Ministry of the Environment were to create an accurate frequency spectrum when a violently changing wind hits a microphone, the Ministry of the Environment's claim would fundamentally destroy physics. I don't have the courage to do that, so don't measure it, and if you find it, exclude it. He said.

If you think of it as wind noise, it will be difficult to explain why the peak values are at 0.2667 Hz and 0.5333 Hz, and the directivity of the wind turbine sound.

・ Wind noise (Part 2)

C-1-2. Ministry of the Environment of Japan, Measurement Manual for Noise Generated by Wind Power Generation Facilities, (3 pages of explanation)

"Wind noise

Noise caused by wind hitting the microphone. In measurement, it is necessary to reduce wind noise by attaching a windscreen (windproof screen) (see 3.1 (2)).

The rustling of leaves and wind noises caused by the wind are natural sounds, not wind noise. "

"3.2 Noise Measurement Instruments

(2) Windscreen

When measuring noise under wind conditions within the effective wind speed range of wind turbines, wind noise cannot be sufficiently reduced with a commonly used windscreen with a diameter of 10 cm or less. To reduce the effects of wind noise, it is necessary to use a larger, all-weather windscreen.

If the influence of the wind is large, use a windscreen with better performance, such as a double windscreen.

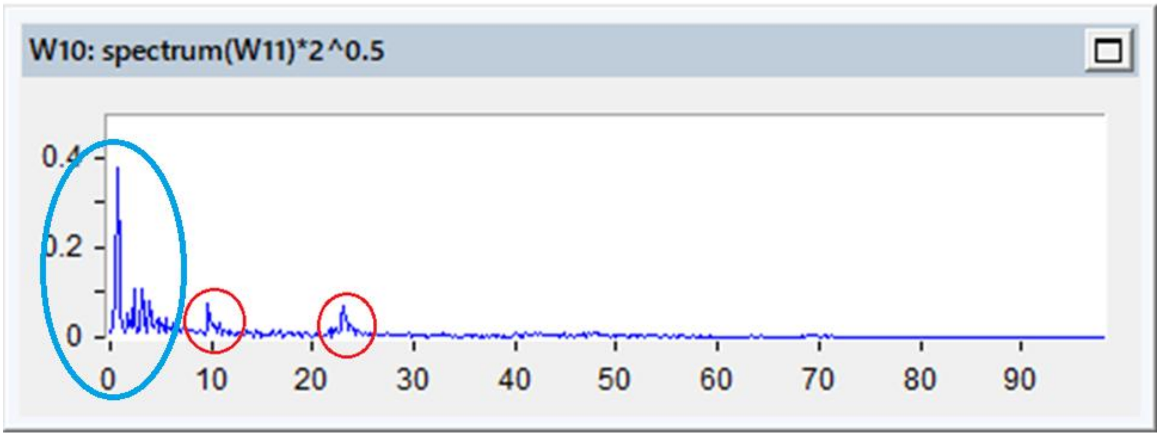
Note: If wind noise cannot be sufficiently excluded even by using double windscreens, etc., it is necessary to take measures such as excluding the area of influence of wind noise by performing sound exclusion processing. "

Here, there is no description related to the frequency of "wind noise", but as an expression for evaluating the performance of the windbreak screen,

(e) Development of a small windbreak screen for measuring wind turbine noise

A spherical windbreak screen made of 20 cm diameter urethane foam and a double windbreak screen with a net attached to a 12-sided metal frame have been developed for the measurement of wind turbine noise in the Ministry of the Environment's strategic designated research (research by evaluating the impact of low-frequency sound on people caused by wind power generation, etc.). Ota et al. (19) reported that as a result of outdoor experiments, a reduction effect of about 10 dB was obtained with a 12-sided windbreak screen alone compared to a 20 cm diameter windbreak screen alone, and by 13 dB (both 8 Hz) when a cube windbreak screen with the same net attached to the outside was added. "

Therefore, if you focus on "13dB (both 8Hz)", it is considered that you are focusing on infrasound frequency sound.



It is the light blue ellipse in the graph above. You can quickly tell whether this is wind noise or not by measuring the sound of the wind-turbine without blowing the wind on the microphone.

・ Suspicious sound

Wind Turbines and Health
A Critical Review of the Scientific Literature
Robert J. McCunney, MD, MPH, Kenneth A. Mundt, PhD, W. David Colby, MD, Robert Dobie, MD,
Kenneth Kaliski, BE, PE, and Mark Blais, PsyD
には、
The main problem with measuring low-frequency sound and infrasound in environmental conditions is wind-caused pseudosound due to air pressure fluctuation, because air flows over the microphone.
With conventional sound-level monitoring, this effect is minimized with a wind screen and/or elimination of data measured during windy periods (less than 5 m/s [11 mph] at a 2-m [6.5 feet] height).36 In the case of wind turbines, where maximum sound levels may be coincident with ground wind speeds greater than 5 m/s (11 mph), this is not the best solution. With infrasound in particular, wind-caused pseudosound can influence measurements, even at wind speeds down to 1 m/s.12 In fact, many sound-level meters do not measure infrasonic frequencies.

It is written.

because air flows over the microphone
The air flowing through the surface of the microphone (vibrating plate) is the cause.
Barometric pressure fluctuations occur, which are recorded as pseudo-sounds.
and
It has almost the same meaning as "wind noise" in the measurement manual.
In this case
In the immediate vicinity of the wind-turbine, infrasound with high sound pressure and regular frequencies was measured, even when the wind did not hit the microphone.
When the sound level meter was placed in a plastic bag, placed in a cardboard box, loaded into the car, and the car door was closed, the sound pressure was higher than in other cases, although the frequency was the same.
This infrasound is not caused by the wind hitting the microphone. In the first place, the wind is not hitting the microphone.

・ The dominant energy of the extremely low frequency component of the wind speed itself

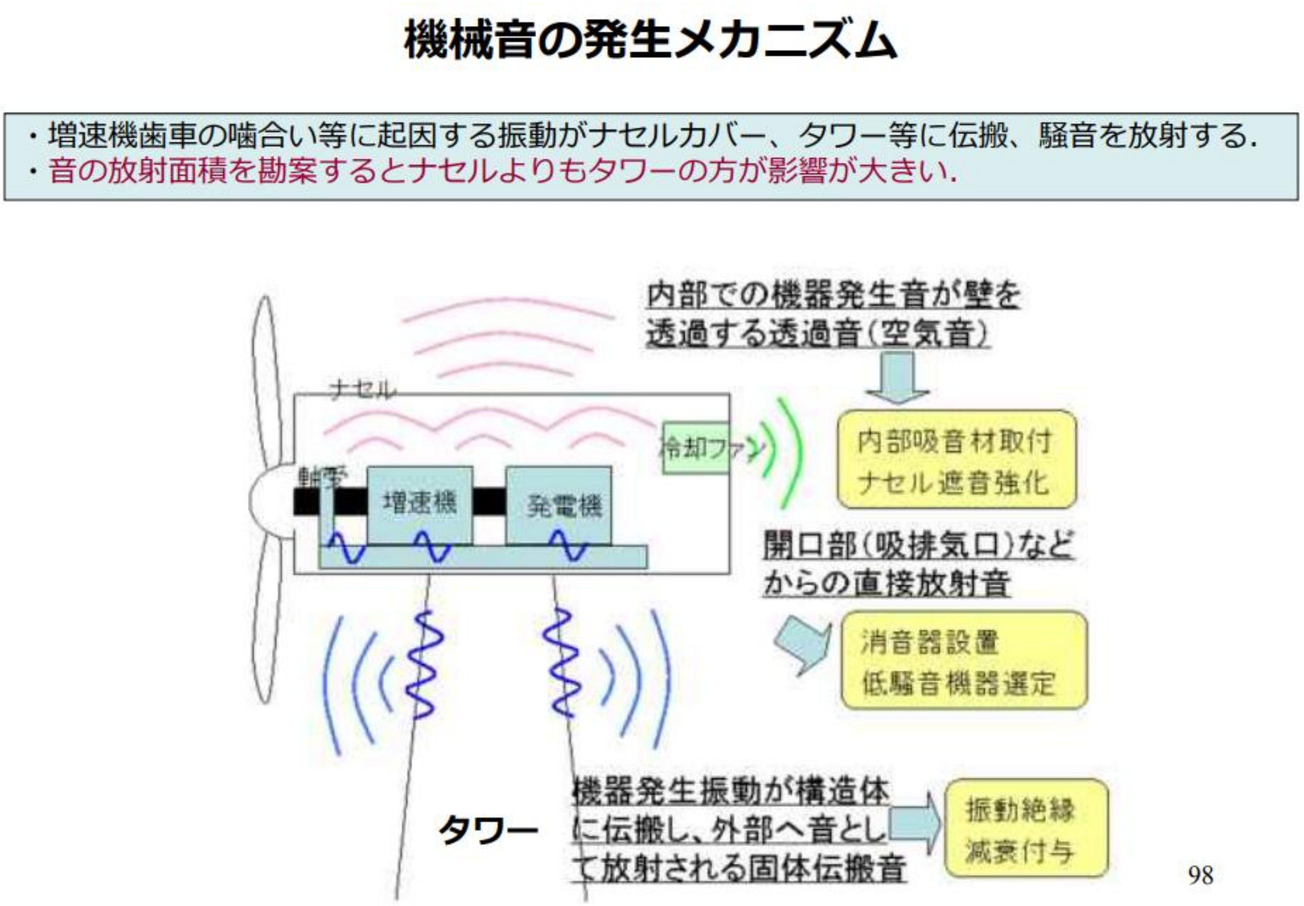
22 Business report on study and investigation on low-frequency sound of moving sources
On p68
Past research on methods for reducing wind noise
and p69 has
(c) Study to clarify the characteristics of the wind itself
Takahashi et al. (17) simultaneously measured wind noise and wind speed fluctuations with a sound pressure level meter for low-frequency sound and a hot-wire anemometer at a certain distance outdoors for the purpose of basic study on the generation of wind noise, and compared wind noise signals and wind speed fluctuations with a frequency range of 200 Hz or less. We found that there is a maximum point of the cross-correlation function between the output signals of the sound pressure level meter at the two measured points with a time delay corresponding to the wind speed at that time, and confirmed the wind noise caused by the passage of the wind mass. On the other hand, there was no maximum point of the correlation function with a specific time delay between the wind signals at two points at the same distance, suggesting that the dominant energy of the extremely low frequency component of the wind speed itself caused the generation of interactive noise in the vicinity of the microphone. “
well
We have already shown that when the wind speed changes, the lift vector changes, the rotation speed of the wind turbine also changes, and the frequency and sound pressure of infrasound change. The wind speed and direction change drastically, and the direction of the blade cannot be changed instantaneously.
Since F = mα, it takes some time for the rotational speed to change even if the magnitude of the lift vector F changes.

"The dominant energy of the extremely low frequency component of the wind speed itself"
If you say that, the story is simple.
In the immediate vicinity of the wind-turbine, measure while blowing the wind through the microphone, measure with a windproof screen, load it in a car and measure it by opening the leeward window, pack it in a cardboard box and measure with the car door closed. And so on, as a result of measuring various changes and
If you compare the results of similar measurements at the same wind speed at a distance of about 20 km from the wind turbine, you can understand the identity of the mysterious energy.

4.3 Shape of the sound source

Noise generated by wind power generation facilities

Date: Wednesday, October 31, 2018 13:30-15:00 Venue: Kumamoto Regional Joint Government Building (Building B) (2-10-1 Kasuga, Nishi-ku, Kumamoto City) IC Engineering Co., Ltd. Engineering Division Yasuo Inoue



The following statement is a rationale for thinking that the shape of a wind-turbine as a sound source should be treated as a line sound source, not a point sound source.

・増速機歯車の噛合い等に起因する振動がナセルカバー、タワー等に伝搬、騒音を放射する
・音の放射面積を勘案するとナセルよりもタワーの方が影響が大きい.

Wind-turbine sounds are directional and emit in a strong form in four directions.

Wind-turbine tower

1) Kota Takahashi, Kazuya Kagawa, Hisaune Nagashima, Hirokazu Kawabata, Motoshi Tanaka, Tetsuya Ogaki, Yukio Hamada, Vibration Analysis of Wind Turbine Nacelle Tower,

Symposium on Wind Energy Utilization, Vol.40, p.251-254, 2018

Do the kind of exercise that you have.

The main direction of motion at the top of the tower is the direction of the lift vector hanging on the blades. Furthermore, the motion of the side of the tower is the direction determined by the lift vector and the direction perpendicular to it.

As a result, as the following paper shows, the wind-turbine emits a sound with a strong directionality.

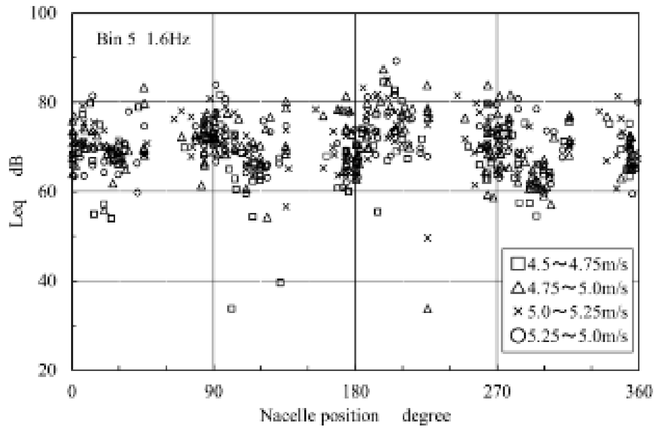


図 6　Bin 5 中心周波数 1.6Hz の指向性分布

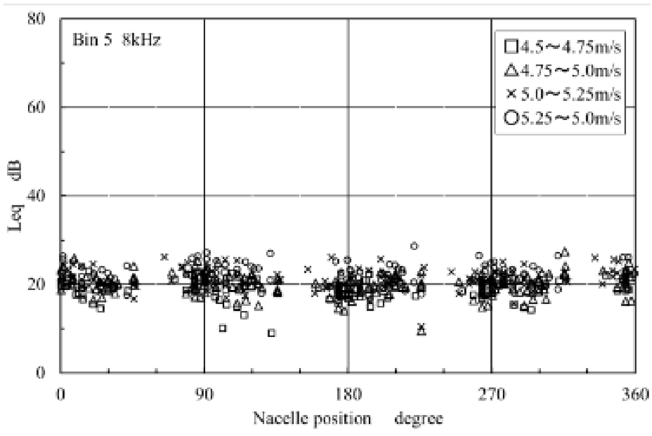
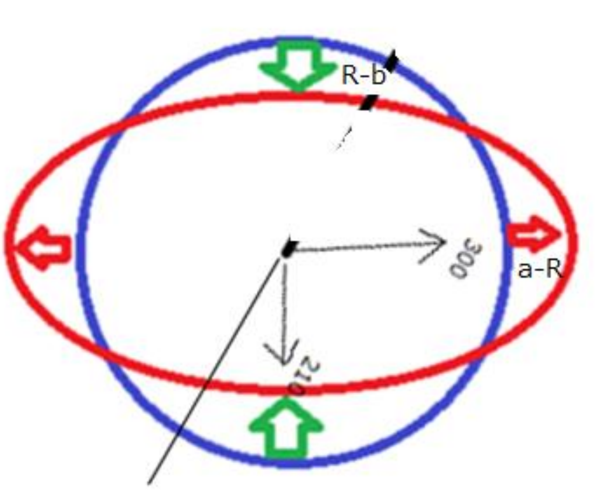
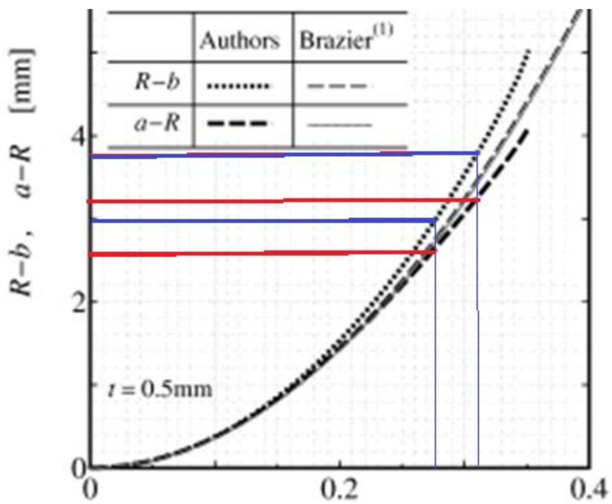


図 9　Bin 5 中心周波数 8kHz の指向性分布

2) Yoshihiro Kikushima, Hisatoshi Nagashima, Shota Hashimoto, Masato Kujioka, Yukio Hamada, Hirokazu Kawabata, Tetsuya Ogaki, Symposium on Wind Energy Utilization *Vol.38, p. 69-72, 2016*

The following paper shows that due to the lift vector, the tower is deformed, and the cut in the horizontal plane of the tower becomes oval.





From the graph above, we can see that if the force applied to the tower fluctuates, the same periodic fluctuation will occur in R-b and a-R.

If you look at the degree of inclination, R-b has a larger slope, so R-b changes more for the same force fluctuation. This means that B will change more than A.

3) Dai-Heng CHEN, Kenichi Masuda, Shingo Ozaki, Studies on Pure Flexural Collapse of Cylindrical Elasto-Plasticity, *Transactions of the Japan Society of Mechanical Engineers, Series A*, Vol.74, No.740, p. 520-527, 2008

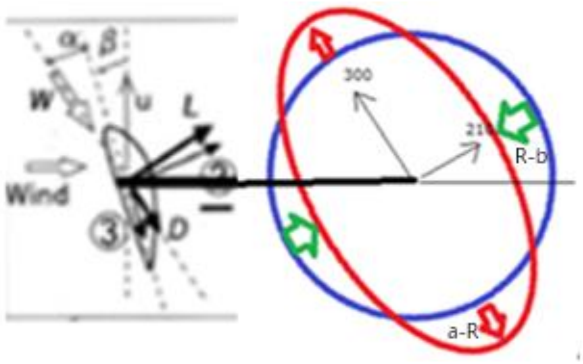
If the side of the wind-turbine vibrates,

6) M.S.Howe, *Aeroacoustics,* Kyoritsu Publishing, First Edition, 2015

As you can see, the sound corresponding to the frequency is diffused in the surroundings.

tuning fork

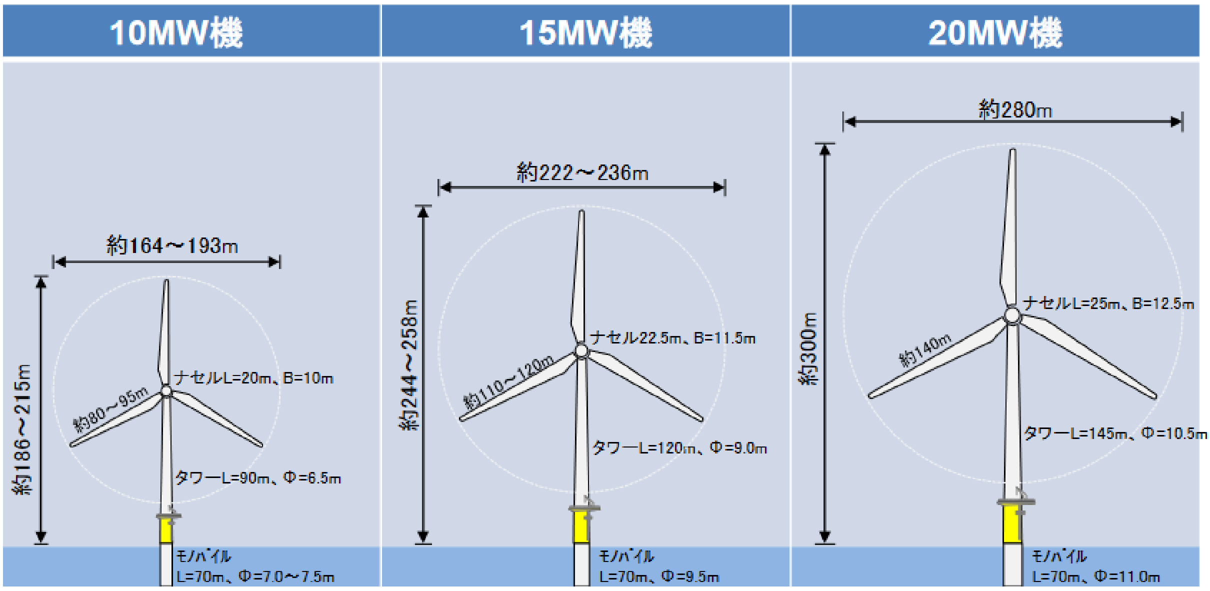
If you compare it to a tuning fork set and a resonance box,



In addition to this, we prepared a plywood of 30 cm * 30 cm.

The left tuning fork does not have a resonance box, so even if you hit it with a hammer, the sound was small.

When the vibrating tuning fork was attached to the plywood, the sound became louder. It is a sensation in the ears, but the frequency does not change.



If the height of the tower is 100 m and the diameter is 10 m, the circumference is 2 * π * 10 = 60 m, which is divided into 4 parts, 60/4 = 15 m
Consider the vibrating surface per unit as 100 m * 10 m.

It is good to understand the sound field of four 100m*10m soundboards.

There is a vertical acoustic box inside the tower of the wind-turbine, and strong sound is emitted in four directions. That's the situation.
This orientation is determined by the direction in which the wind-turbine is facing. Since the wind-turbine tower is large, it should be treated as a surface sound source in the vicinity and a linear sound source in a slightly distant area.

2) Yoshihiro Kikushima, Hisatoshi Nagashima, Shota Hashimoto, Masato Kujioka, Yukio Hamada, Hirokazu Kawabata, Tetsuya Ogaki, Symposium on Wind Energy Utilization Vol.38, p. 69-72, 2016

In order to predict the damage caused by wind-turbine sounds, it is necessary to consider the directivity of the wind-turbine sound and the shape of the sound source.

In order to determine the shape of the sound source, it is necessary to elucidate the physical mechanism by which sound is generated.

4.4 Natural frequency of wind-turbines

A group at the University of Tokyo has published the results of investigating the mechanical vibration of wind turbines.

A Study on Field Observations of Actual Wind Turbines and Their Vibration Characteristics
○ The University of Tokyo Student Member: Pham Van Phuc
The University of Tokyo Regular Member Meng Ishihara
The University of Tokyo Fellow Yozo Fujino
TEPCO Regular Member Yukinari Fukumoto

3.2 Wind turbine frequency Figure 3 shows the power spectral density obtained from the waveform of the response acceleration obtained by observation, and clear peaks are seen around 0.5 Hz, 2.0 Hz, 6.8 Hz, and 8.9 Hz. The lower frequencies of 0.5 Hz and 2.0 Hz correspond to the primary natural frequencies of the wind turbine tower and the primary natural frequencies of the wind turbine blades, while the other frequencies may correspond to the higher natural frequencies of the blades, towers, or the natural frequencies of the blade-to-tower coupling modes.3)

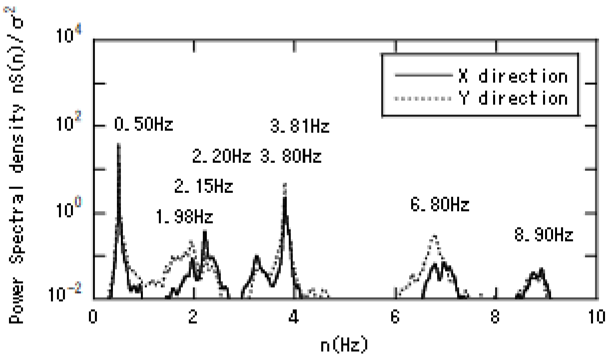


図3　応答加速度のパワースペクトル密度

3.3 Wind-turbine damping Wind-turbine damping includes two parts: structural damping and aerodynamic damping, and it is difficult to strictly separate them. In this study, the RD method was used as in Ref. 3, and the damping ratio was obtained from the response acceleration, and the rotor speed and wind speed were shown together in Figure 4.

Although the damping ratio varies depending on the wind speed, the average value of the damping ratio in the nacelle direction is about 0.5%, while the attenuation ratio in the orthogonal direction of the nacelle increases with the increase in wind speed. As the wind speed increases, the number of revolutions of the rotor and the drag acting on the blades increase. This seems to increase the aerodynamic damping acting on the blades.

表 1 固有振動数の観測値と予測値との比較

No	観測 (Hz)	固有値解析 (Hz)		
		ブレード	タワー	風車全体
1	0.50	2.19	0.54	0.50
2	0.50	4.73	0.54	0.51
3	1.98	-	4.36	2.10
4	2.15	-	4.36	2.19
5	2.20	-	-	2.20
6	-	-	-	3.26
7	3.80	-	-	3.46
8	3.81	-	-	3.91
9		-	-	4.77
10		-	-	5.05

As you can see, we emphasize the natural vibration of the blades and towers.

4.5 Analysis and Generation Mechanism of Infrasound

Analysis of Infrasound and Generation Mechanism

Yasumasa UYAMA
Personal member of Japan Wind Energy Association.

Abstract
This document provides the results of analysis of the sound from wind turbine, and the mechanism of infrasound generation.

The part of the infrasound near the wind turbine is described as wind noise and the frequency is not examined in detail. However, when this feature is investigated, it becomes clear that the directivity of the wind turbine sound, the shaking of the top of the tower, and the vibration around 40 m above the ground of the tower are related, and it is found that the wind turbine generates directional infrasound.

For wind noise, "Low-frequency wind noise is caused by wind hitting the microphone. This noise has a louder component as the frequency decreases. In the frequency range of about 5 Hz or less (in some cases about 10 Hz or less), it is difficult to eliminate wind noise." It is said,

Even if the wind is strong, the component of 10 Hz or less in a place where there is no wind turbine has an extremely low sound pressure and no regular wind noise. Even if the wind is not so strong, near the wind turbine, the sound pressure of the component below 10 Hz is high, and wind noise with regularity appears.

This is either to think that there are two types of wind noise: "wind noise in places where there are no wind turbine" and "wind noise in places where there are wind turbines", or to think that infrasound with high sound pressure is generated from wind turbine.

Keywords: infrasound frequency, wind noise, lift vector, rotational moment, tower vibration
Key Words：Infrasound, wind noise, lift vector, moment of rotation, vibration of tower

1. Introduction

The components of wind-turbine noise below 5 Hz are considered to be "wind noise" and "if this is removed, the original wind-turbine sound can be obtained. However, by analyzing the frequency and clarifying the cause of the vibration of the wind turbine, it is shown that this sound is "extremely low frequency sound caused by the wind turbine".

2. Measurement Instruments and Analysis Targets

Measuring equipment: NL-62, NX-42WR, Analysis target: A wind turbine with a horizontal axis of rotation located on a hill in Kazenooka, Tateyama City, Chiba Prefecture*1

3. Noise Comparison

Compare frequency spectra to show features.

(The horizontal axis is frequency hertz [Hz], and the vertical axis is sound pressure Pascal [Pa])

Fig.1 : The sound inside the JFE steel mill(0～5000Hz)

Fig.2: Sound measured near the wind-turbine (0~5000Hz)

Fig.3: Sound measured near the wind-turbine (0~25Hz)

Fig.4 : Sounds in the precincts of Nagao Shrine(0～25Hz)

Fig. 1 and Figure 2 are comparisons in the range of 0~5000Hz, and the sound in the steel mill is broadband, but the sound of wind-turbines is concentrated near 0.8Hz in the left corner and is not a wideband sound.

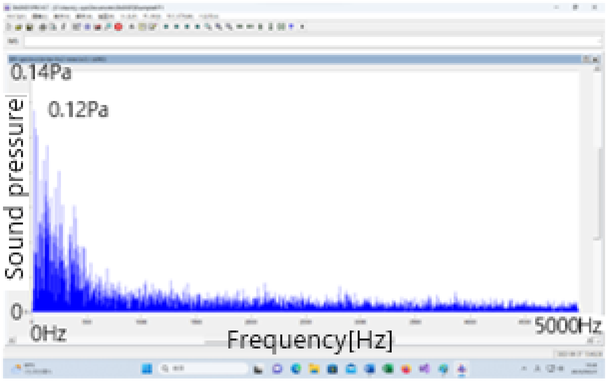


Fig.1 JFE iron mill ; Max 0.12[Pa](12Hz)

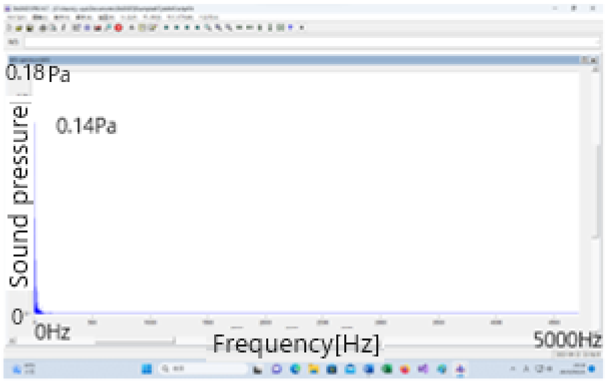


Fig.2 Wind turbine noise ; Max 0.14[Pa](0.8Hz)

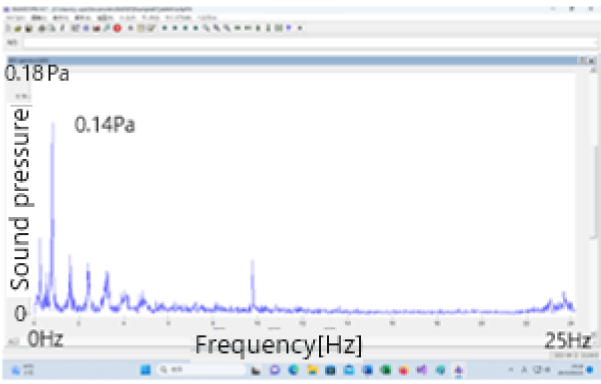


Fig.3 Wind turbine noise (0～25Hz)

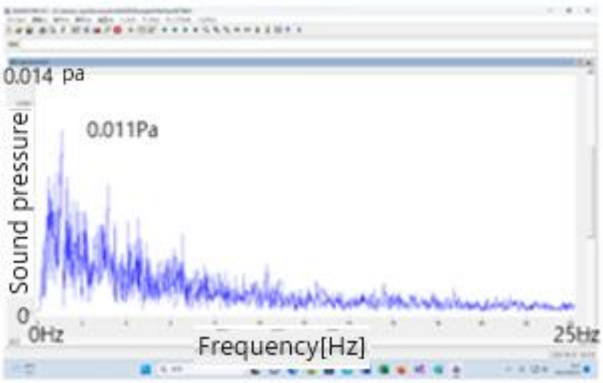


Fig.4 Nagao shrine (0～25Hz); 0.011[Pa](1.1Hz)

Fig. 3 Figure 4 shows the sound measured in the range of 0~25 Hz by placing equipment in the car near the wind-turbine and opening the leeward window (maximum sound pressure 0.14 [Pa] (0.8 Hz)), and the sound measured with a microphone placed on the stairs of the nearby Nagao Shrine and exposed to the wind (maximum sound pressure 0.011 [Pa]). (1.1Hz)) It is a comparison with. Table 3 describes in detail the regularity of "wind noise" near wind turbines. From Fig. 4, it can be seen that the sound pressure is low and there is no regularity in frequency in places where there are no wind-turbines. It is necessary to distinguish between these "wind noises".

Table 1 Table 2 shows the energy distribution for each frequency band.

Energy distribution	0～20Hz	20～5kHz
Wind turbine	93%	7%
Iron mill	12%	88%

Table 1 Energy distribution (0～5000Hz)

Energy distribution	0～1Hz	1～20Hz	0～20Hz
Wind turbine	61.3%	38.7%	100.0%
Iron mill	0.04%	99.96%	100.0%

Table 2 Energy distribution (0～20Hz)

From Table 1, if we consider wind-turbine noise as noise (frequency of 20 Hz or higher), we ignore 93% of the sound energy. As a result, the percentage of people who complain of discomfort is compared with the figure that excludes the part that causes discomfort, such as a feeling of pressure, and there is a large error compared to the case of traffic noise.

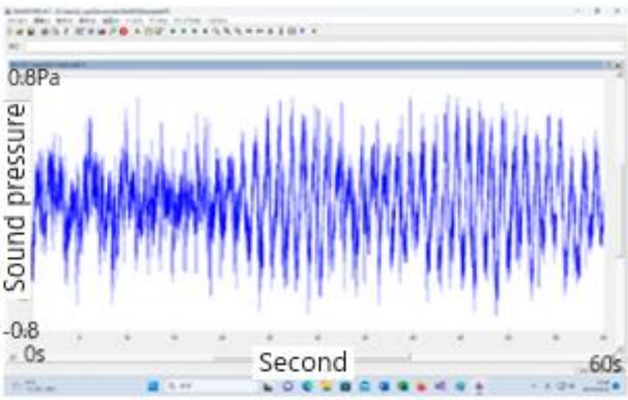
From Table 2, it can be seen that the 0.8Hz part accounts for 61% of the sound energy of 0~20Hz. Therefore, infrasound should not be limited to 1~20Hz.

4. Wind-turbine sound and playback sound

Figure 5 shows the sound of a wind-turbine recorded by NL-62 for 60 seconds. Figure 6 shows the sound being divided using FFT, and blue is represented as a component of 0~20Hz, green as 20~200Hz, and red as 200~24kHz. Figure 7 shows the sound of Figure 5 played back by the PC speakers, and the sound recorded by NL-62 again is divided in the same way as Figure 6.

In Figure 6, amplitude modulation can be seen in the 200Hz~24kHz component, but the effect on the room is weak considering the extremely low sound pressure and air attenuation and energy transmittance. Conversely, the energy of infrasound is large, and its effects should be carefully investigated.

Except for the feeling of pressure, it was not possible to distinguish the difference between the sound heard near the wind-turbine and the sound from the speakers by hearing.



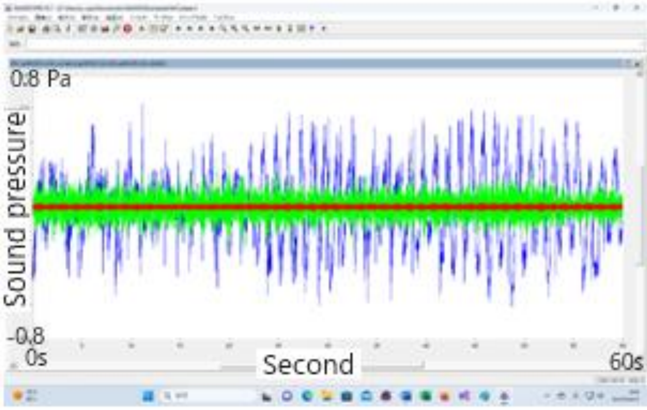


Fig.5 Wind turbine noise

Fig.6 Separated Wind turbine noise

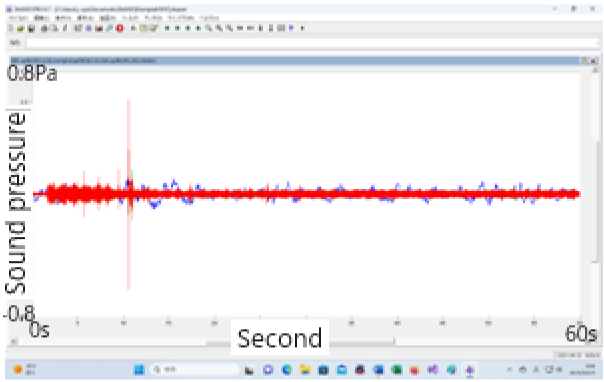


Fig.7 Separated sound from speaker

It can be seen from FIG. 7 that the speaker sound does not include infrasound frequency. Even large speakers cannot reproduce sound below 1 Hz. This is the reason why there is a difference in the feeling of pressure between the sound of a wind-turbine and the sound played back in the laboratory. If you want to do an experiment, you have to build a laboratory in the bed of a trailer and go near the wind-turbiine.

5. Detailed characteristics of wind-turbine sound

Table 3 shows the correspondence between the peak value of the sound pressure in FIG. 3 and the frequency at that time.

Frequency at peak[Hz]	Rate(1)	Rate(2)	Sound pressure[Pa]
0.2667	1.0000		0.0560
0.5333	2.0000		0.0309
0.8167	3.0625	1.0000	0.1405
1.5833	5.9375	1.9388	0.0436
2.4167	9.0625	2.9592	0.0242
3.2167	12.0625	3.9388	0.0317
4.0000	15.0000	4.8980	0.0177
4.8667	18.2500	5.9592	0.0173
5.4667	20.5000	6.6939	0.0101
6.2667	23.5000	7.6735	0.0098

Table 3 Frequencies of the peak values

The frequency of 0.8 Hz at the maximum sound pressure corresponds to f = RZ / 60 [Hz] when the rotation speed of the blades is R (rpm) and the number of blades is Z (sheets). If we elucidate the mechanism by which sound is generated, including other frequencies, we will understand why infrasound is generated.

6. Fine fluctuations in frequency

From f = RZ / 60 [Hz], the frequency changes with the number of revolutions. From the Wavelet graph of FIG. 8, it can be seen that the frequency changes between 0.73 Hz and 0.87 Hz.

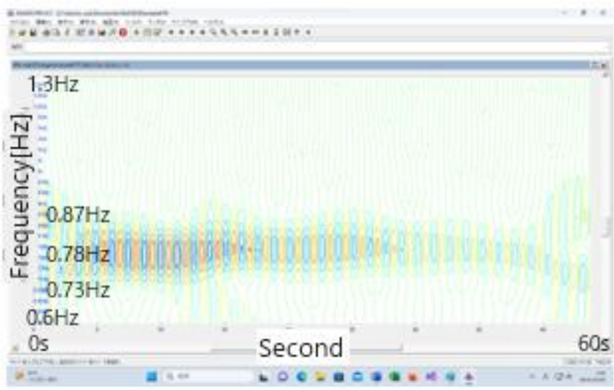


Fig.8 Fine fluctuation nearby 0.8Hz

Rotation (7times), a part of large table		
Brade pass	Time(second)	Frequency[Hz]
21	28[s]	0.75[Hz]
21	22[s]	0.95[Hz]
21	28[s]	0.75[Hz]
21	28[s]	0.75[Hz]
Average		0.8 [Hz]

Table 4 Fine fluctuation from video

Table 4 shows a part of the frequency calculated from the state of rotation taken on video. The frequency changes finely in response to the change in wind speed, which coincides with the change in Figure 8.

Since the dark part in FIG. 8 indicates that the sound pressure is high, and since FIG. 8 is a measurement result for 60 seconds, it can be seen that the high sound pressure continues for about 20 seconds. From the measurement results for 10 minutes, it can be seen that the sound pressure of the frequency component close to 0.8 Hz is 0.10 [Pa] when the wind is light, 0.37 [Pa] when the wind is strong, and about 0.18 [Pa] on average.

7. Tower The direction of vibration and the directivity of the wind-turbine sound

The direction and magnitude of the vibration on the nacelle and the side of the tower 40 meters above the ground, as well as the directivity of the sound, are considered while paying attention to the direction of the lift vector. (1.6Hz is due to the high rotation speed of small wind turbines.))

"Vibration Analysis of Wind-turbine Nacelle Tower"1)

Then, for the nacelle portion, ″In the rolling direction of FIG. 3, an increase in gain can be seen at 0.8 Hz, 1.6 Hz, and 2.7 Hz, and the eccentricity of the rotor is not remarkably visible, and instead the vibration of the number of blades × the number of revolutions appears at 1.6 Hz. This is due to blade deformation vibration due to the wind speed and the number of blades up, down, left and right″″ Figs. 4 and 5 show the 210 degree and 300 degree direction spectra of the nacelle vibration. ″In the 210 degree direction, the rotor rotation frequency of 0.5 Hz appears slightly, and the number of blades × 1.6 Hz is remarkable″, and from Figs. 6 and 7 of 1), it can be seen that a component of 1.6 Hz is also displayed in the 210 degree direction and 300 degree direction in the 40 m vibration in the tower.

"Effect of wind speed on wind turbine noise directionality'"2)

"The level of the 200-degree position is increasing, and this position is the position where the cancellation mechanism works and the level decreases, and the opposite phenomenon of directivity is displayed. It can be seen from Figure 6 in 2) that the sound pressure is high in the directions of 20 degrees, 110 degrees, 200 degrees, and 290 degrees.

Referring to "Study on elasto-plastic pure bending collapse of cylinders" 3), the fluctuations in the side of the tower are shown in Fig. 9 and Fig. 10.

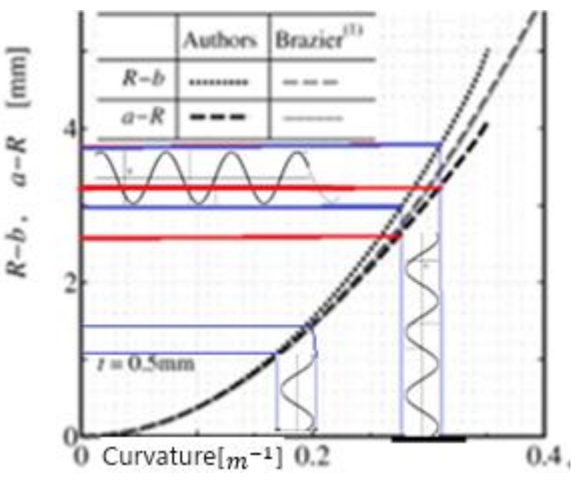


Fig.9 Force fluctuation and side vibration

FIG. 9 shows that the sides of the tower vibrate in response to changes in the force applied to the tower. The vibration width on the side is larger on the right.

The cross-section of the tower becomes an ellipse when the cylinder bends, as shown on the right side of FIG. The vibration of the side in the direction of the applied force and the vibration of the side in the direction perpendicular to it are generated. As a result, the wind-turbine sound is directional, and the frequency coincides with the frequency of the force applied to the tower. Furthermore, if the cross-section changes from a circle to an ellipse, the area decreases, so the volume in the tower decreases. Conversely, if the cross section approaches the circle, the volume increases. The deformation of the tower also causes fluctuations in the air pressure in the tower.

8. Force on wind-turbines and their effects

According to "Fluid Mechanics (Part 1)"4),

The lift L acting on the wing is from the Kutta-Jopukowski theorem.

$$L = \rho U \Gamma = 4\pi \rho U^2 \lambda \sin(\alpha - \delta) \qquad (1)$$

The lift force is proportional to the square of the uniform velocity U.

Considering the proximity of the distance between the blade and the tower, and investigating the periodic change in the magnitude of the lift L and the rotational moment with respect to the tower, the state of deformation of the tower and the cause of the wind-turbine sound can be determined, and the frequency and sound pressure of the wind-turbine sound can be determined.

In "Wind turbine vibration analysis" 5), after describing the lift L, the force applied to the wind turbine is discussed.

"Wind speed varies with height, so as the blades rotate, these forces change periodically, resulting in periodic excitation forces on the blades and the tower."

"Each frequency component of the force applied from the blade to the tower is multiplied by several times, and as described above, a large excitation force with a frequency nP n times the rotational speed is applied." He stated.

"A large excitation force with a frequency nP n times the rotational speed" lacks consideration of the directivity of the wind-turbine sound, and does not lead to how the tower deforms and produces sound.

"Aeroacoustics"6) describes how sound is generated by vibrating objects.

In order to consider the vibration of the side of the wind-turbine, it is necessary to calculate from the perspective of the force applied to the tower by shifting the viewpoint to the rotational moment applied to the tower. The deformation of the tower is similar to the case of a fishing rod bending. The deformation of a fishing rod is determined by the moment of rotation with respect to the fishing rod. The upper part can be shaken in a circle, but the side swing is accompanied by deformation of the cut.

The wind-turbine rotates by lift, and the rotation speed is adjusted by changing the angle of the blades. At the start of rotation, the direction of the blade is adjusted so that the component of the rotation direction is large, and the direction of the lift vector is set to 200 ~ 210 degrees during rated output operation to suppress the rotation of the blade. As a result, the component in the direction of the axis of rotation of the lift force becomes larger.

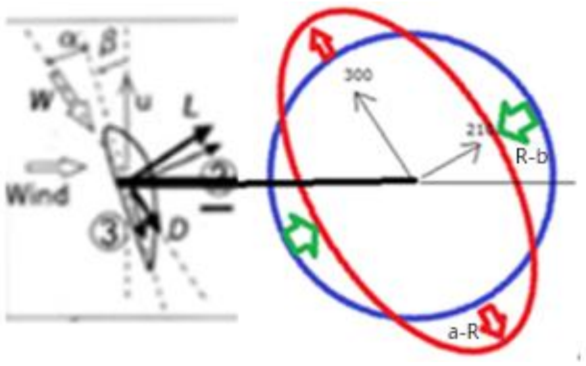


Fig. 10 Lifting vector and modification

9. Force and rotational moment on the tower

(Calculated as a 9-digit number and rounded to the end.))

Regarding the shaking of the nacelle and tower, the direction of the lift vector when the blade is directly above should be emphasized, but here we consider the component of the lift vector in the direction of the axis of rotation.

Simplifying, assuming that the height of the tower is 100 m, and instead of blades, a plate shaped like a round sign is attached 50 m from the center, and the frequency is calculated.

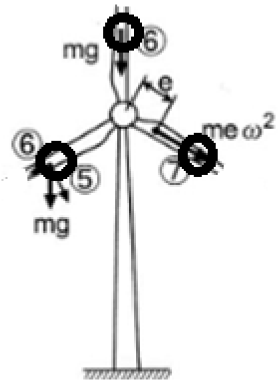


Fig. 11 Wind turbine in balance

The height of the disk above the ground is m$100 + 50 * \sin(\omega t + \theta)$

Become.

Winds blow stronger in the sky than near the surface. There are several formulas for predicting wind speed in the sky, but we use the following formula:

Wind speed atZ_{h1} heightV_{Zh1}

Predicted wind speed at$Z_{G(V)}$ height$V_{ZG(V)}$

Ground surface roughness distinction V. Power index according to Index α (v).

And when the following equation is

$V_{ZG(V)}/V_{Zh1} = (Z_{G(V)}/Z_{h1})^{\alpha(V)}$ (2)

is established in the countryside.$\alpha(V) = 0.15$
In rural areas, when the wind speed is 7 [m/s] at 10 m above the ground,
The wind speed at 100 + 50 * sin（ωt + θ）m above the ground is

$7 * ((100 + 50 * \sin(\omega t + \theta))/10)\verb|^|0.15$ [m/s] (3)

Become.

Assuming that the air density is 1.23 [kg/m^3], the wind force coefficient Cd = 1.2, and the wind speed is V [m/s], P: The wind load [N/㎡] is

P = （V^2／2）×1.23×1.2 [N/㎡] (4)

When the area of the sign is 10 [㎡], and when the wind blows at 10 m above the ground and the wind is 7 [m/s], the force applied to the round plate attached to the wind-turbine is:

$$P = \frac{\left(\left(7 * \left(\frac{(100 + 50 * \sin(\omega t + \theta))}{10}\right)^{0.15}\right)^2\right)}{2} * 1.23 * 1.2 * 10 \quad [N] \qquad (5)$$

Become. This force is proportional to the square of the wind speed.
The force that tries to knock down the wind-turbine caused by this force is the moment of rotation when the axis of rotation is a straight line shared by the surface of the earth and the rotating plane of the blade.

$[P * (100 + 50 * \sin(\omega t + \theta)) = k * (100 + 50 * \sin(\omega t + \theta))\verb|^|1.3\mathrm{Nm}]$ (6)

(k=181.24). Here

$(100 + 50 * \sin(\omega t + \theta))\verb|^|1.3$ (7)

Focus on the part.
Since the angle of the blade is 2π/3, the rotational moment M is
When ω = 2π ・ 0.8/3,

$$f(t) = (100 + 50 * \sin(\omega t))^{1.3} + (100 + 50 * \sin(\omega t + 2\pi/3))^{1.3} + (100 + 50 * \sin(\omega t + 4\pi/3))^{1.3} \quad (8)$$

If so

$$M = k * f(t) = 181.24 * f(t)[\mathrm{Nm}] \quad (9)$$

Become. McLoughlin Deployment

$$(1 + x)^{\alpha} = 1 + \frac{\alpha}{1!}x + \frac{\alpha(\alpha-1)}{2!}x^2 + \frac{\alpha(\alpha-1)(\alpha-2)}{3!}x^3 + \cdots \quad (10)$$

to calculate. (The calculation in SIN is shown, but the same applies to COS.))

Approximate calculation on a calculator (0.8 Hz basis)

$$(100 + 50 * \sin(\omega t))^{1.3} = (100^{1.3})(1 + (1/2) * \sin(\omega t))^{1.3} \quad (11)$$

If you substitute (1/2) sin(ωt) in the expanded equation,

$$(100 + 50 * \sin(\omega t))^{1.3} = 398.11 * \{1 + 0.65\sin(\omega t) + 0.05 sin^2(\omega t) - 0.006 sin^3(\omega t) + \cdots\} \quad (12)$$

Become. Pay attention to the following equation when calculating:

$$\sin(x) + \sin(x + 2\pi/3) + \sin(x + 4\pi/3) = 0 \quad (13)$$

$$sin^2(x) + sin^2\left(x + \frac{2\pi}{3}\right) + sin^2\left(x + \frac{4\pi}{3}\right) = \frac{3}{2} \quad (14)$$

$$sin^3(x) = (3\sin(x) - \sin(3x))/4 \quad (15)$$

So, out of the sum of the cubes of sin, the sum of sin(x) is 0, and the sum of sin(3x) is

$$\sin(3x) + \sin\left(3\left(x + \frac{2\pi}{3}\right)\right) + \sin\left(3\left(x + \frac{4\pi}{3}\right)\right) = 3\sin(3x) \quad (16)$$

Because it will be

$$sin^3(x) + sin^3\left(x + \frac{2\pi}{3}\right) + sin^3\left(x + \frac{4\pi}{3}\right) = -(3/4)\sin(3x) \quad (17)$$

consequently

$$(1f(t) \approx 1223.43 + 1.70\sin(3\omega t)8)$$

Become.

When the three blades are rotating according to sin (ωt), sin (ωt + 2π / 3), sin (ωt + 4π / 3),
The moment of rotation on the tower is

$$M = k * f(t) \approx 221734.19 + 307.78\sin(3\omega t) (19)$$

If the rotation frequency of the blade is 0.26666 Hz, the moment applied to the tower changes at a frequency of 0.8 Hz.

It can be seen that the rotational moment changes with a period of 1/3 of the rotation period of the blade.

(2) Unequal な場合 (0.27Hz, 0.53Hz の根拠).
Now consider the case where only one of the blades is slightly larger than the other two.

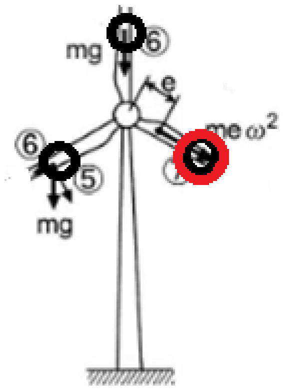


Fig. 12 Wind turbine imbalance

If the area of the large part is 10 * 1.003 = 10.03 ㎡, the force received by the red circle part at this time is

$$P = \frac{\left(\left(7 * \left(\frac{(100 + 50 * \sin(\omega t + \theta))}{10}\right)^{0.15}\right)^2\right)}{2} * 1.23 * 1.2 * 10 * 1.003 \quad [N] \qquad (20)$$

than

$$P * (100 + 50 * \sin(\omega t + \theta)) = k * ((100 + 50 * \sin(\omega t + \theta))^{1.3} + 0.003 * (100 + 50 * \sin(\omega t + \theta))^{1.3})$$
(21)

Become. Assuming that $\theta = 0$ is large,

$$g(t) = f(t) + 0.003 * (100 + 50 * \sin(\omega t))^{1.3} \quad (22)$$

Think. (Equation (8) was used.))

$$0.003 * (100 + 50 * \sin(\omega t))^{1.3} = 0.003 * 398.11\{1 + 0.65\sin(\omega t) + 0.05sin^2(\omega t) - 0.006sin^3(\omega t) + \cdots\} \quad (23)$$

Then, if the power term is expressed in a double angle and calculated,

$$M = k * g(t) = 221955.93 + 139.77\sin(\omega t) - 5.28\cos(2\omega t) + 308.08\sin(3\omega t) + \cdots \quad (24)$$

Obtain. This is the basis for the appearance of 0.27 Hz and 0.53 Hz components in extremely low frequency sound.

（3）0.8Hz、1.6Hz、2.4Hz、…Grounds for the appearance of
Notice the following proposition:

The proposition can be expressed by a constant and a linear equation of (m = 1 ~ n). ($(sinx)^n$ $\sin(mx)\cos(mx)$ The same applies to COS)

If n=1, then is $(sinx)^1 = \sin(1x)$ correct.
Assuming that it is true when n = k,

$$(sinx)^{k+1} = f_k(x) * sinx \quad , \quad (25)$$

Constant *sinx satisfies the requirement

$$\sin(mx) * sinx = -(\cos(mx + x) - \cos(mx - x))/2 \quad (26)$$

$$\cos(mx) * sinx = (\sin(x + mx) + sin(x - mx))/2 \quad (27)$$

Therefore, equation (25) can be expressed by a constant and a linear equation of (m = 1 ~ k + 1). $\sin(mx)\cos(mx)$

Therefore, it can be written in the following form. $(sinx)^n = f_n(x)$

$$f_n(x) = c_n + \sum_{m=1}^{n} a_m \sin(mx) + \sum_{m=1}^{n} b_m \cos(mx)$$

(28)

Therefore

$$(sinx)^n + (\sin\left(x + \frac{2\pi}{3}\right))^n + (\sin(x + \frac{4\pi}{3}))^n$$

(29)

To consider, the sum of the first-order equations

$$\sin(mx) + \sin\left(m(x + \frac{2\pi}{3})\right) + \sin(m\left(x + \frac{4\pi}{3}\right))$$

(30)

You just have to find out.
m=3k, m=3k+1, m=3k+2 (k=0,1,2,...)
Consider the case separately.
If m=3k, then

$$\sin(3kx) + \sin\left(3kx + \frac{6\pi k}{3}\right) + \sin\left(3kx + \frac{12\pi k}{3}\right) = 3 * \sin(3kx) \quad (31)$$

If m=3k+1, then

$$\sin((3k+1)x) + \sin\left((3k+1)x + \frac{6\pi k + 2\pi}{3}\right) + \sin\left((3k+1)x + \frac{12\pi k + 4\pi}{3}\right) = 0$$

(32)

(The same applies to m = 3k + 2). consequently

$f_n(x) + f_n(x + 2\pi/3) + f_n(x + 4\pi/3)$ (33)

leaves only terms and constants of the form , , . This is$\sin(3mx)\cos(3mx)$ why it peaks at frequencies greater than 0.8 Hz, 1.6 Hz, 2.4 Hz, 3.2 Hz, and 4.0 Hz.
In equations (8) and (9), even if the expansion equation of (10) is lengthened,
Only the constant term and the term , remain.$\sin(3m\omega t)\cos(3m\omega t)$

In addition to the force of the lift of the blades, the tower also has the force of the wind blowing on the tower itself, which causes it to bend slightly downwind. Since the wind speed varies depending on the height, the lift of the blades periodically changes the force applied to the tower. Even if the three blades are perfectly evenly distributed and the wind is stable, in addition to 3*R/60[Hz], 2*3*R/60[Hz], 3*3*R/60[Hz]、4*3*R/60[Hz]、…Shaking occurs.

In addition, if one blade is slightly larger, or if the angle to the wind is slightly different from the other two, In addition to R/60[Hz], the fluctuation of wind turbines also includes the shaking of 2*R/60[Hz] and 3*R/60 [Hz].

When this force acts on the tower, the cut edge of the tower becomes an ellipse, causing vibrations on the sides of the tower. As a result, an extremely low-frequency sound with directionality in the direction of large vibrations on the sides is generated.

The sound generated by the vibration of the tower caused by the rotation of the blades, which has a regular frequency, should not be called "wind noise". "Extremely low-frequency sound is emitted from wind-turbines."

FIG. 4 represents "wind noise", but FIG. 3 represents infrasound from a wind turbine. It is characterized by the directivity and frequency regularity of sound.

Figure 13 shows an image of a musical instrument with two drums on the body and a flute on the top. This is a schematic diagram showing the mechanism by which sound is generated from a wind-turbine after considering the characteristics of wind turbine sound, including pressure fluctuations in the tower.

Fig. 13 Image of Wind turbine noise

10. Indoor Measurement and Chaos Theory

"Modeling House Filters for Low-Frequency Noise"7) states, "Indoor sound fields are complex and contain many physically difficult problems, especially in the low-frequency range. It is written.

It is difficult to analyze the sound in a room, but chaos theory can overcome the difficulty. FIG. 14 is an analysis for finding a machine that is out of order from the noise in the steel plant.

The first stage is a noise graph, the second stage is the frequency spectrum, and the third stage is wavelet analysis. The characteristics are unknown in the analysis so far, but if you use "Average Wavelet Coefficient-Based Detection of Chaos in Oscillatory Circuits"8), you will get a fourth-row graph.

Fig. 14 Effect of Chaos theory

The fourth stage is a graph that looks like a camel sitting, with one bump representing one natural frequency, and two bumps representing the vibration of two natural frequencies. The graph in the middle shows that a square sieve with two natural frequencies is the cause.

11. Things to be aware of in wind-turbine sounds

In order to investigate the relationship between sound pressure and pressure, it is necessary to treat the maximum sound pressure as a Pascal value. In addition, with regard to fluctuations in sound pressure, it is necessary to consider the possibility of bubble generation due to acoustic cavitation. If small bubbles form in the body, it will be the same as diving sickness and cause headaches. Even the slightest possibility should be considered in detail. ("Bubble Engineering"9))

12. Conclusion

It has been shown that the horizontal-axis wind-turbine is the very generator of infrasound waves, but there is still a beacon of hope in the Eiffel Tower in Paris. There, a vertical-axis wind-turbine that is quiet and has little vibration generates electricity. There is no reason for the generation of infrasound from vertical-axis wind turbines.

(In February 2015, two wind turbines were installed at the Eiffel Tower about 120 meters above the ground.))

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For details, please see "Wind-turbine Infrasound 2023".

4.6 Compression and Expansion

The human body is seen as a sphere with a radius of 0.5 m. Surface area is 4*3.14*0.5*0.5=3.14 ㎡

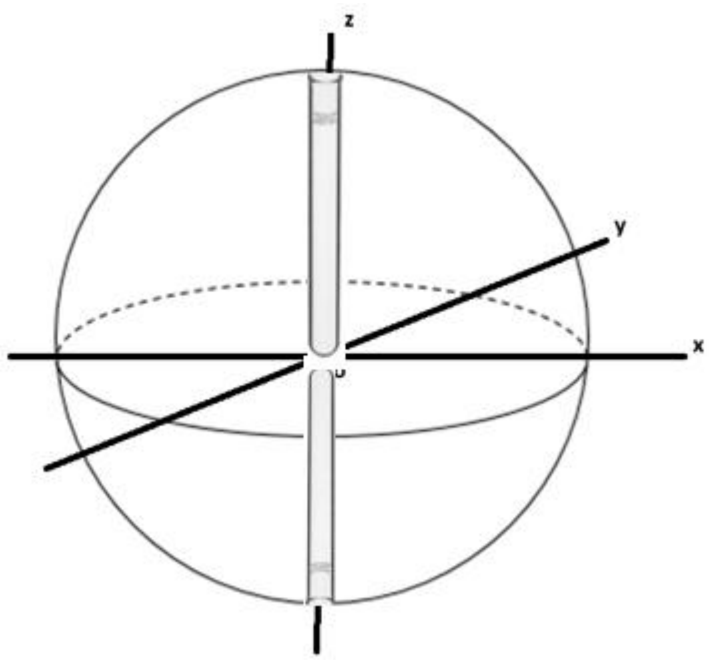
The surface part has a mass equivalent to body weight (60 kg), and the surface density is 60/3.14 = 19 kg/m^2

Suppose that the x-axis is perpendicular to the wavefront of the sound (plane wave).

The speed of sound shall be 340 m/s.

For the Pascal value, 1 Pascal is defined as the pressure or stress exerted by a force of 1 Newton (N) per square meter (m2) of area.[1]

For Newton, 1 Newton is the force that causes an acceleration of 1 m/s2 in an object with a mass of 1 kg.



Think of it as two examiners for the North Pole and the South Pole.

試験管の半径をr＝0.005m、断面積を ds＝ π *0.000025＝0.0000785 [m^2]、

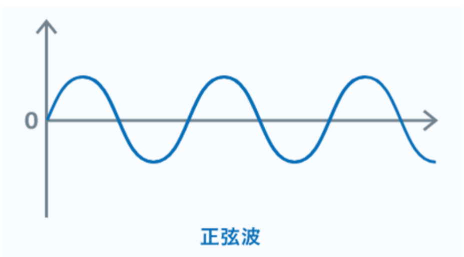
The density of the shell portion is ρ = 19.1 kg / m ^ 2 .

The mass of the mouth of the test tube is M = ρ * ds = 19 * π * 0.000025 = 0.0015 [kg].

This part is considered to be the passage of a plane wave parallel to the yz plane.

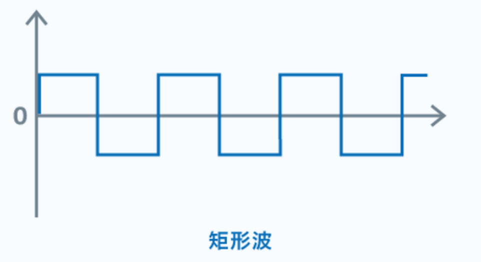
The sound pressure P(t) at the mouth of the test tube is

$$P(t) = Asin\omega t$$



としたいのだが、

To simplify the calculations, consider in terms of square waves.



Set the atmospheric pressure before the sound comes. Suppose that the pressure in the test tube was the same.P_0

The pressure exerted on the lid of the test tube is repeated with.$P_0 + AP_0 - A$

Consider the case where a sound wave of 1000 Hz passes through.

The speed of sound is 340 m/s, so the wavelength is 340/1000 = 0.34 m

$P_0 + A$The length of the part is 0.17m = 170cm

The time it takes for this part to pass through the lid part is 0.17/340 = 0.0005 seconds

Therefore, every 0.0005 seconds, the pressure applied to the lid changes.

If the internal pressure is and the external pressure is increased, the force applied to the lid is (A* area of the lid) Pascal.$P_0 P_0 + A$

If this state continues for dt seconds, from F = m α ,

A*ds=M α

α =A*ds/M

After dt seconds, the measure v1 = α dt, and the travel distance is the initial velocity v0 = 0.

dl=(1/2) α (dt)^2+v0*dt

Become.

If the length of the test tube is L, the volume of the test tube is L * ds. After dt seconds, the volume in the test tube changes to ds * (L-dl) because the lid has moved.

Since the volume has decreased, the air pressure in the tube rises.P_1

For the time being, it is assumed that the temperature of the gas in the tube is the same. (I'll fix it later.)

$P_1 * ds * (L - dl) = P_0 * ds * L$

Therefore, the state after dt seconds is

v1= α *dt

dl=(1/2) α (dt)^2

$$P_1 = P_0 * L/(L - dl)$$
$$L_1 = (L - dl)$$

Become.

Next, consider the external pressure as , and the internal pressure as . The initial velocity at this time is V1,$P_0 + AP_1 = P_0 * L/(L - dl)$

The pressure difference on the lid presses on the lid DS part.$P_0 + A - P_1$

As an acceleration,$\alpha_1 (P_0 + A - P_1) * ds = M * \alpha_1$

$$\alpha_1 = \frac{(P_0 + A - P_1) * ds}{M}$$

$$dl_1 = v1 * dt + \left(\frac{1}{2}\right) \alpha_1 * dt^2$$

$$v2 = v1 + \alpha_1 * dt$$

The volume in the test tube, as the lid has moved, changes to .$ds * (L - dl - dl_1)$

The pressure in the test tube is more$P_2 P_2 * ds * (L - dl - dl_1) = P_1 * ds * (L - dl) = P_0 * ds * L$

$$P_2 = P_1 * (L - dl)/(L - dl - dl_1) = P_0 * L/(L - dl - dl_1)$$

$$L_2 = (L - dl - dl_1)$$

Next, consider the external pressure as , and the internal pressure as .$P_0 + AP_2 = P_0 * L/(L - dl - dl_1)$

The pressure difference on the lid presses on the lid DS part.$P_0 + A - P_2$

As an acceleration,$\alpha_2 (P_0 + A - P_2) * ds = M * \alpha_2$

Initial velocity is v2

$$\alpha_2 = \frac{(P_0 + A - P_2) * ds}{M}$$

$$dl_2 = v2 * dt + \left(\frac{1}{2}\right) \alpha_2 * dt^2$$

$$v3 = v2 + \alpha_2 * dt$$

The volume in the test tube, as the lid has moved, changes to .$ds * (L - dl - dl_1 - dl_2)$

The pressure in the test tube is more$P_3 P_3 * ds * (L - dl - dl_1 - dl_2) = P_0 * ds * L$

$$P_3 = P_0 * L/(L - dl - dl_1 - dl_2)$$

$$L_3 = (L - dl - dl_1 - dl_2)$$

Next, consider external pressure as internal pressure.$P_0 + AP_3 = P_0 * L/(L - dl - dl_1 - dl_2)$

The pressure difference on the lid presses on the lid DS part.$P_0 + A - P_3$

As an acceleration,$\alpha_1 (P_0 + A - P_3) * ds = M * \alpha_3$

Initial velocity is v3

$$\alpha_3 = \frac{(P_0 + A - P_3) * ds}{M}$$

$$dl_3 = v3 * dt + \left(\frac{1}{2}\right) \alpha_3 * dt^2$$

$$v4 = v3 + \alpha_3 * dt$$

The volume in the test tube, as the lid has moved, changes to .$ds * (L - dl - dl_1 - dl_2 - dl_3)$

The pressure in the test tube is moreP_4 $P_4 * ds * (L - dl - dl_1 - dl_2 - dl_3) = P_0 * ds * L$

$$P_4 = P_0 * L/(L - dl - dl_1 - dl_2 - dl_3)$$

$$L_4 = (L - dl - dl_1 - dl_2 - dl_3)$$

Next, consider external pressure as internal pressure.$P_0 + AP_4 = P_0 * L/(L - dl - dl_1 - dl_2 - dl_3)$

The pressure difference on the lid is the force that pushes the lid DS part.$P_0 + A - P_4$

As an acceleration,$\alpha_1 (P_0 + A - P_4) * ds = M * \alpha_4$

Initial velocity is V4

$$\alpha_4 = \frac{(P_0 + A - P_4) * ds}{M}$$

$$dl_4 = v4 * dt + \left(\frac{1}{2}\right) \alpha_4 * dt^2$$

$$v5 = v4 + \alpha_4 * dt$$

The same applies hereinafter.

Become.

If the above calculation is made as dt = 0.00125 seconds, L = 0.5 m, M = ρ * ds = 0.0015 kg, A = 1,

The internal pressure rises until dt*k = period / 2, but after that, the external pressure becomes and the external pressure becomes$P_0 - A$

The air in the test tube begins to expand. This expansion continues only during cycle 2. After that, the external pressure becomes and also enters the compression process.$P_0 + A$

The pressure in the test tube at the end of the first compression process is shown in the following table.

周波数	0.5	1	2	10	20	50	100	200
周期/2	1	0.5	0.25	0.05	0.025	0.01	0.005	0.0025
内気圧	102400.9991	102400.9742	102400.861	102400.467	102400.369	102400.303	102400.132	102400.033

回数	外気圧	外力	気柱長さ	気柱体積	内気圧	内力	気圧差	外力－内力	初速度	加速度	終速度	移動距離 dl	開始秒	終了秒
0	102401	8.0384785	0.5000000000	0.00003925	102400	8.0384	1	7.85E-05	0	0.05233333	6.5417E-05	4.08854E-08	0	0.00125
1	102401	8.0384785	0.4999999591	3.925E-05	102400.0084	8.03840066	0.99162667	7.7843E-05	6.5417E-05	0.05189513	0.00013029	1.22314E-07	0.00125	0.0025
2	102401	8.0384785	0.4999998368	3.925E-05	102400.0334	8.03840262	0.96657677	7.5876E-05	0.00013029	0.05058418	0.00019352	2.02376E-07	0.0025	0.00375
3	102401	8.0384785	0.4999996344	3.925E-05	102400.0749	8.03840588	0.92513015	7.2623E-05	0.00019352	0.04841514	0.00025403	2.79719E-07	0.00375	0.005
4	102401	8.0384785	0.4999993547	3.92499E-05	102400.1322	8.03841037	0.86784356	6.8126E-05	0.00025403	0.04541715	0.00031081	3.53026E-07	0.005	0.00625
5	102401	8.0384785	0.4999990017	3.92499E-05	102400.2045	8.03841605	0.79554369	6.245E-05	0.00031081	0.04163345	0.00036285	4.21034E-07	0.00625	0.0075
6	102401	8.0384785	0.4999985806	3.92499E-05	102400.2907	8.03842282	0.70931554	5.5681E-05	0.00036285	0.03712085	0.00040925	2.90007E-08	0.0075	0.00875
7	102401	8.0384785	0.4999985516	3.92499E-05	102400.2966	8.03842328	0.70337617	5.5215E-05	0.00040925	0.03681002	0.00045526	2.87578E-08	0.00875	0.01
8	102401	8.0384785	0.4999985229	3.92499E-05	102400.3025	8.03842375	0.69748653	5.4753E-05	0.00045526	0.0365018	0.00050089	2.8517E-08	0.01	0.01125

When the amplitude of the barometric pressure fluctuation is 1 pascal,

At 200 Hz, the pressure in the body increases by 0.033 pascals before entering the decompression process.

At 100 Hz, the pressure in the body increases by 0.132 pascals before entering the decompression process.

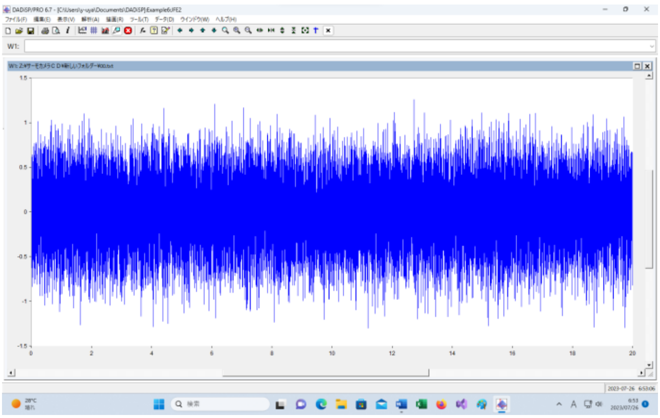
At 10 Hz, the pressure in the body increases by 0.467 pascals before entering the decompression process.
At 1 Hz, the pressure in the body increases by 0.974 pascals before entering the decompression process.
At 0.5 Hz, the pressure in the body increases by 0.999 pascals before entering the decompression process.

The lower the frequency, the greater the pressure fluctuations in the body.
Above 200 Hz, the pressure in the body changes little, but below 10 Hz, considerable compression occurs.
This is not a feeling of oppression, but a feeling of pressure itself.

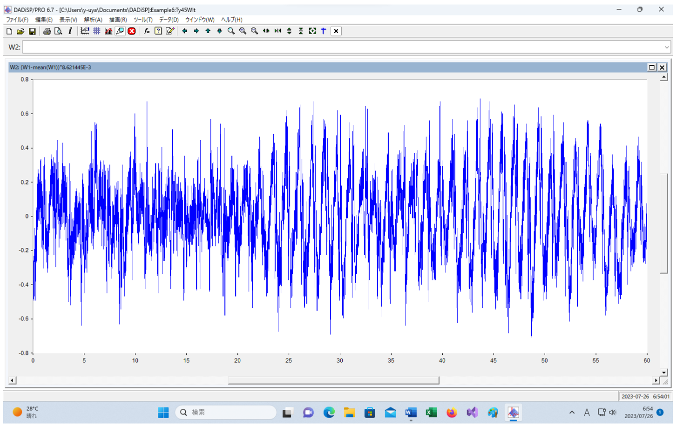
This pressure fluctuation tilts the equilibrium state of dissolution and development of bubbles in the body toward the one with the most occurrence.

The calculation here can only be applied if the waveform is close to a square wave.

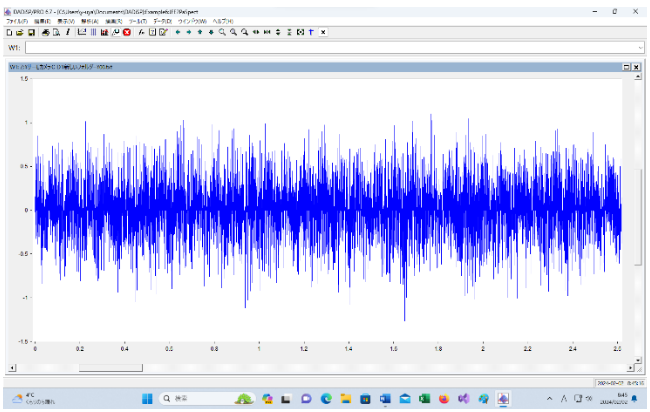
Sounds inside JFE's steel mills



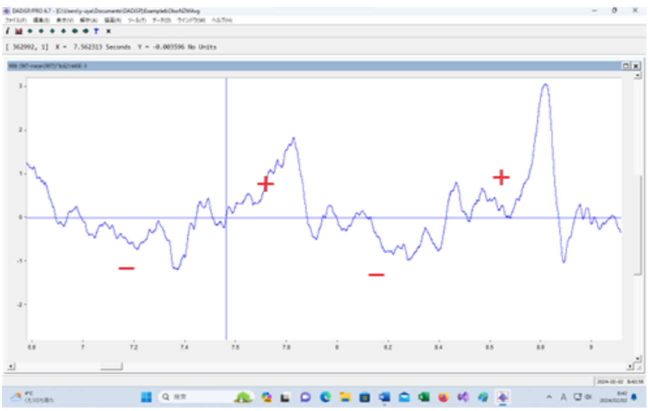
The sound of windmills in Tateyama



2.6 seconds waveform of factory noise

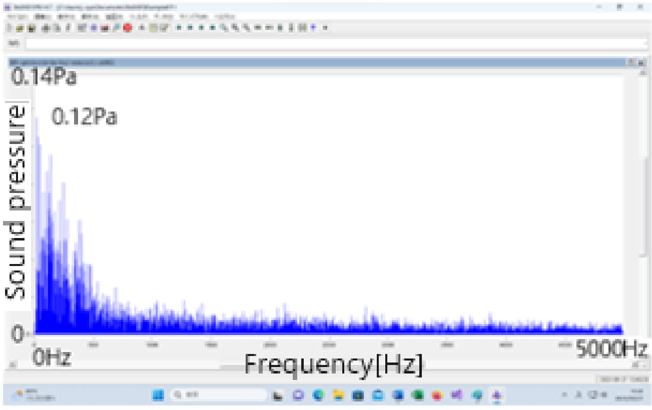


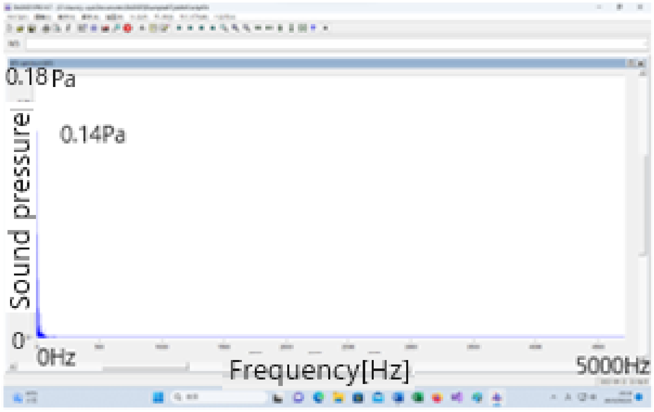
2.2 seconds waveform of windmill sound



ironworks(0~5kHz) ; maximum0.12[Pa](12Hz)

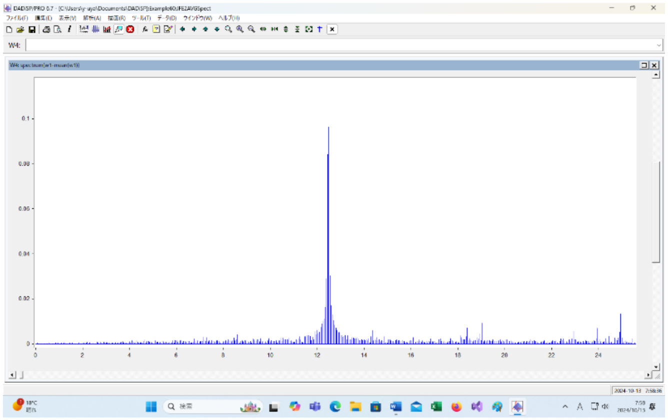
Windmill sounds(0~5000Hz); Max sound pressure .14[Pa](0.8Hz)

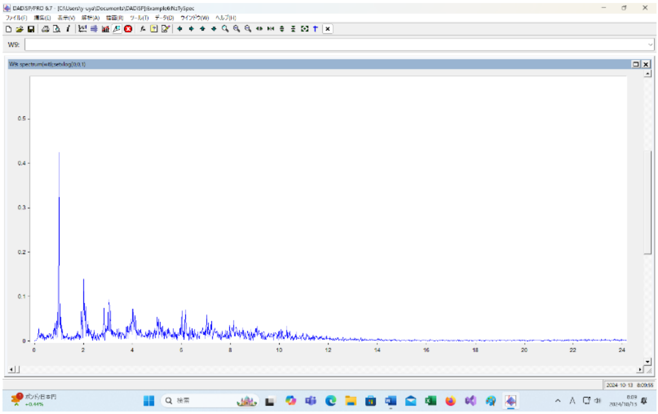




Factory Noise0～25Hz、Max0.1[Pa]（12.5Hz）

Windmill sound (strong wind)0～24Hz、Max0.42[Pa]（1Hz）





Distribution of energy

周波数帯	0 ～20Hz	20～200Hz	200～24ｋHz	0～24ｋHz	単位
交通騒音	1.76E-07	8.08E-08	1.80E-05	1.80E-05	W/m2
神社風	8.23E-06	3.91E-07	2.12E-07	8.83E-06	W/m2
JFE工場	4.80E-05	4.01E-04	5.34E-04	9.84E-04	W/m2
風車弱風	8.19E-04	2.40E-05	3.82E-07	8.43E-04	W/m2
風車強風	1.49E-03	2.30E-05	6.94E-08	1.52E-03	W/m2

The sound pressure at the factory is 0.1 Pascals at 12.5 Hz, but it can be said that the waveform is determined by the 20~24 kHz part, both in terms of energy and from the recorded waveform. Since the sound pressure fluctuates greatly, the compression and expansion processes cannot be continued, so there is no power to greatly change the pressure in the body.

In windmill sounds, if you look at the distribution of energy, the components of 0~20Hz are overwhelmingly strong, and this part determines the waveform.

In strong winds, compression and expansion occur in a form similar to sound pressure fluctuations due to waves of f = RZ / 60 Hz.

At f = 0.5 Hz and f = 1 Hz, the magnitude of the sound pressure fluctuation and the sound pressure fluctuation in the body are about the same.

As a result, acoustic cavitation in the body does not occur in factory sounds, but it is thought that windmill sounds do.

4.7 Circulatory Disorders Due to Long-Term Exposure

The following is an article in the Changzhou Newspaper.
Elucidation of the effects of low-frequency sound on the human body from a report by Dr. Mariana Alves Pereira Dr.

"As a result, tumors were found in the kidneys and brain. It was a tumor that could not be detected by previous screenings. The most surprising thing was that he had 11 scars from a heart attack due to an infarction. He died of his twelfth seizure. The twelfth scar was less than 2 millimeters in size and was small in size, which is not usually considered an infarction scar. In addition, an unusual thickening of the cardiovascular structure was found, which is unthinkable.

And the part called the pericardium was also thickened. The pericardium, which is the membrane of the heart, is very thin, and the normal thickness of the pericardium is less than 0.5 millimeters. However, patients exposed to low-frequency sound have pericardium as large as 2.3 millimeters.

This is a photograph of the pericardium of a patient who has undergone heart surgery [see photo (1)]. Both had cardiovascular abnormalities. The person on the left was not caused by the noise, and the person on the right was caused by the noise. It can be seen that the pericardium is abnormally thickened.

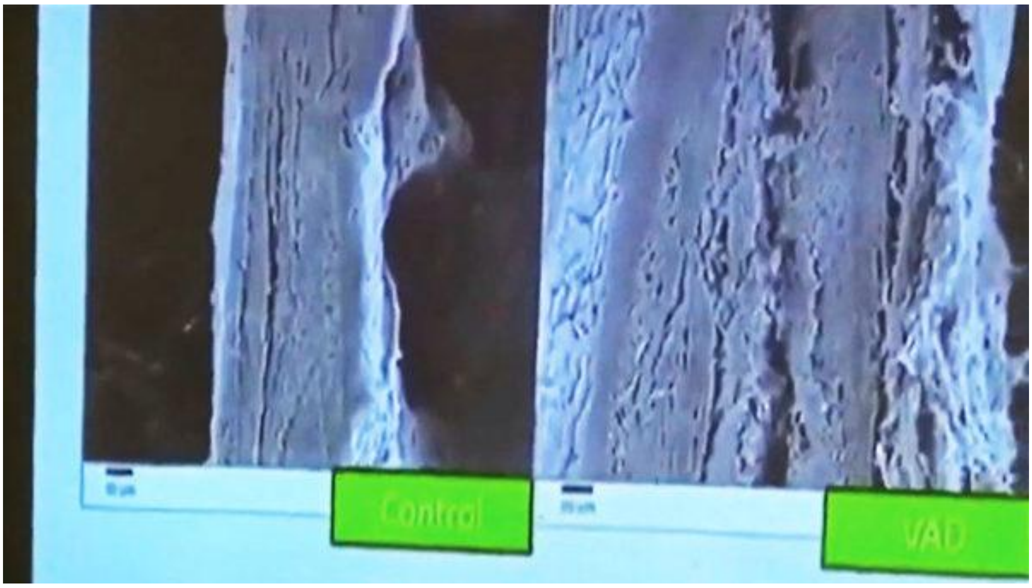


Photo (1) Photograph of the pericardium of a patient who underwent heart surgery. On the right is the patient caused by noise. Thickened (the magnification is the same)

Thickening of cardiovascular structures does not occur only in the pericardium. It also occurs in blood vessels. Occurs in the walls of blood vessels. The walls of the blood vessels through which blood flows are naturally thin, but they thicken.

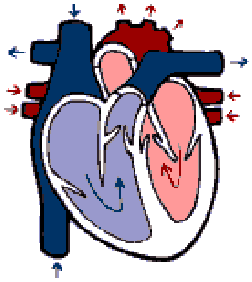
When the walls of the arteries become thicker and thicker, the arteries close. Patients exposed to low-frequency sound close their blood vessels not because of the buildup of cholesterol in their blood vessels, but as a result of the thickening of their walls. For example, the coronary veins are very small and quickly become clogged. So, in the case of this staff, there were as many as 11 infarction marks. When that happens, there is no more blood, so there is a problem.
We believe that this thickening is caused by an abnormal increase in collagen and elastin. The technical term is morphogenesis. It means the development of an organization that should not be there. At first, I had no idea that this was happening because of low-frequency sound. It happened because the entire body was exposed to a "mechanical force that is not dependent on living things," and the body tried to counter that force.
In 1999, he decided to study the way the disease progressed. Based on a group of 306 aeronautical engineers, people with cardiovascular disease, diabetes, streptococcal infections, and people taking tranquilizers were excluded, and the remaining 140 men were included in the study. After four years of exposure to low-frequency sound during engine tests, more than 70 (more than 50%) developed bronchitis. In 10 years of exposure, more than 70 people developed hematuria.
Another important thing was that the symptoms were accumulating. He has bronchitis, which adds to the bleeding in his nose and severe muscle pain. Hematuria also does not stop. “
He stated.

It is thought that the pressure fluctuation in the body due to the influence of the sound of the windmill is greater than the sound of the aircraft. The reason lies in its frequency characteristics. This is because the lower the frequency, the greater the effect on pressure fluctuations in the body.
The reason why he didn't notice this was because:
The physical mechanism of windmill noise was not elucidated.
I was too focused on octave analysis, so I couldn't grasp the exact frequency (f=RZ/60Hz) and sound pressure.
There is a thing.

None of hypertension
In relation to hypertension, when the entire body is compressed, the diameter of peripheral blood vessels also decreases, and the resistance of peripheral blood vessels increases, making it difficult for blood to flow. At this time, blood pressure rises.

高血圧とは

血液は全身に張り巡らされた血管を流れて、身体の各部分に養分と酸素を供給し老廃物を回収しています。この血液は心臓が収縮することで、動脈に押し出され、心臓が拡張するときに静脈から心臓に戻ります。
心臓が収縮するときに動脈の血管にかかる圧力を収縮期血圧と言い、心臓が拡張してもなお血管内に残っている圧力を拡張期血圧と言います。
この血圧は体内を循環している血液の量と心臓の収縮で送り出される血液量とで決まりますが、どちらの量も増加することで血圧が上昇します。



また、同時に血管壁の弾力性も血圧を決定する要因の一つで、血管がしなやかだと、血液の量が増えても血管壁が膨らんで血圧が急に高くなることを防ぎます。逆に血管に弾力性がないと血管の内圧が高まり血圧が上昇します。これを血管の抵抗と言います。実際には太い血管から枝分かれした抹消血管が硬くなり内空が狭くなって血流が流れづらくなって抹消血管の抵抗が増加した場合に血圧が上昇するようです。

高血圧は痛みやめまいなどの自覚症状に乏しく、そのため軽く見てしまいがちです。しかし、それをほうっておくと動脈硬化が進行し、脳卒中や心臓病などの命にかかわる合併症を引き起こします。

さらに、

4. 高血圧で起きる病気

高血圧を放置しておくと体中の血管の壁に強い負担がかかります。すると、その刺激で血管は収縮し、さらに血管の内腔は狭くなります。また、血管壁には強い圧力がかかるため血管壁自体も補強され厚くなり、その結果さらに内腔は狭くなって、動脈硬化が促進されます。
動脈硬化による血管の内腔の狭窄が進めば血液の流れは悪くなり、やがて血流は完全に途絶えてしまいます。 血液は全身に酸素や養分を運んでいるので、その血流が悪くなると全身にさまざまな支障を与える重大な病気を引き起こしてしまいます。
次に、高血圧によって引き起こされる代表的な病気について考えてみましょう。

1）動脈硬化症	血管の壁が厚くなって弾力性が失われるなどして、もろくなり、内腔が狭くなった状態を言います。
2）脳卒中	脳の血管がもろくなって破れ、脳出血が起こります。また動脈硬化で脳の血管が詰まれば脳梗塞が引き起こされます。
3）心臓病	心臓の筋肉を養っている冠状動脈が動脈硬化で狭くなると狭心症を引き起こします。狭くなった血管が血栓で詰まると心筋梗塞となり命にかかわる大事になります。

So,

The walls of blood vessels seem to thicken.

It increases the likelihood of arteriosclerosis, stroke, and heart disease.

I was told by a doctor I know.

"Large blood vessel walls, such as the aorta, can be evaluated by MRI and CT, and recent ultrasound examinations (echo) of blood vessels are quite advanced, and if they are of the latest type, they can be evaluated considerably. On the other hand, the evaluation of the venous wall is quite difficult, and it can only be evaluated for blood clots in the veins. In addition, capillaries are the most susceptible to exogenous causes, but it is currently difficult to evaluate them with images. ”

I was told.
Both the exposure to extremely low-frequency sound and the thickness of the arterial vessel walls can be objectively measured, providing statistical evidence of causality.

A smartwatch can also be used to grasp the physical condition of the subject.

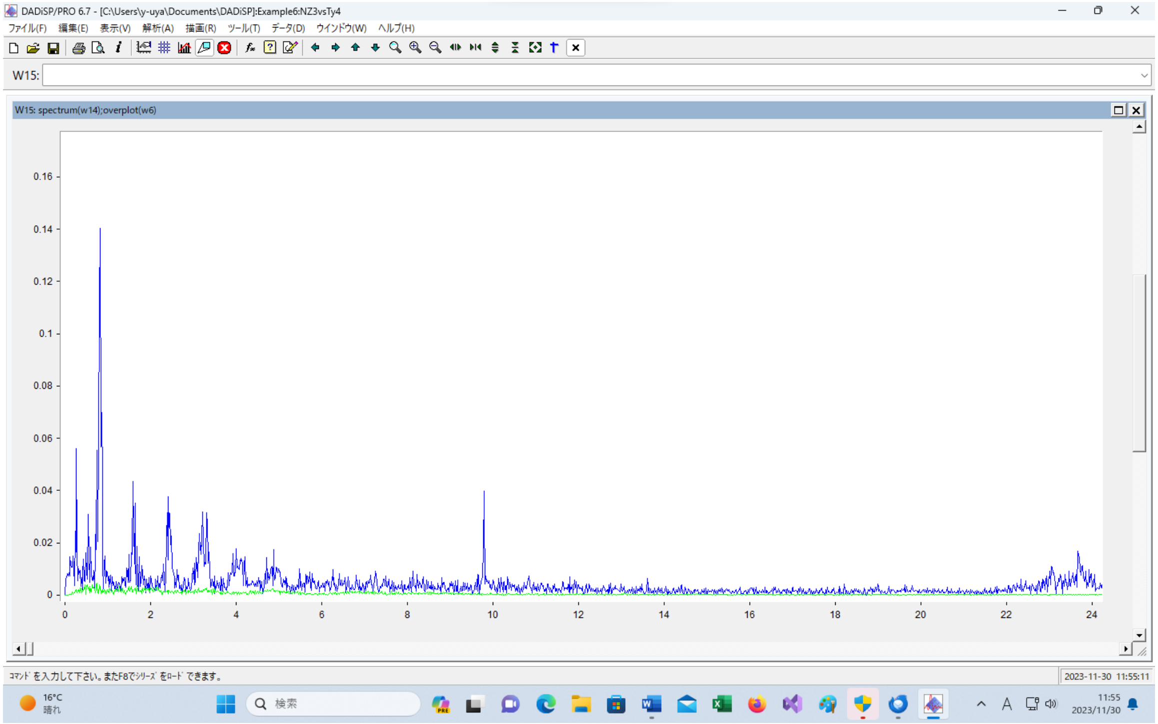
One piece of evidence for a connection between this number and the result of placing a precision sound level meter near a sleeping person and placing a continuous velocity measurement for 6 hours can be analyzed by Wavelet.

Changes in flow rate and blood pressure in peripheral blood vessels will be described in more detail with reference to the following materials.

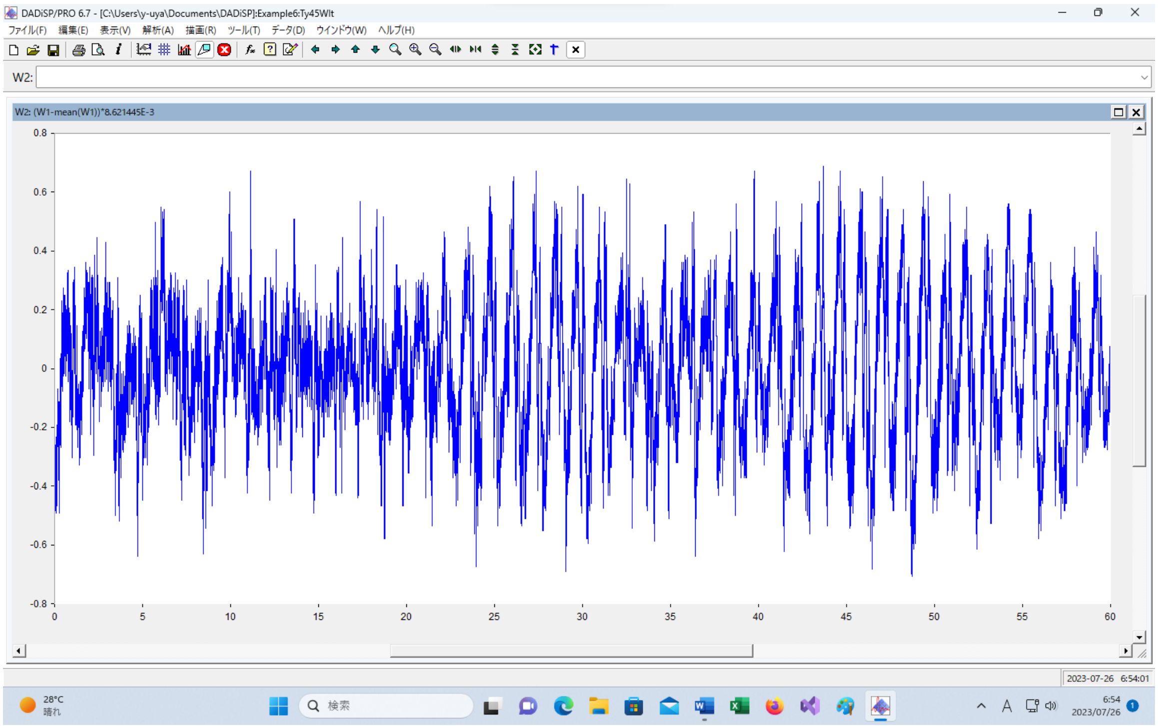
Propagation of Stress Waves and Reflection and Transmission in Impact Problems
Various Elastic Waves (Part 1)
Stress wave propagation in the genus of gold (the basis of the dynamics of high-speed transformation)

4.8 Acoustic cavitation and headaches

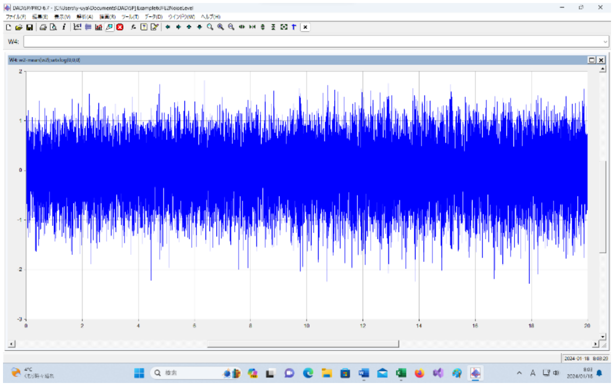
From the frequency spectrum of the windmill sound, it can be seen that the infrasound from the windmill is discrete, and that the component of f=RZ/60=1 Hz has an outstanding sound pressure.

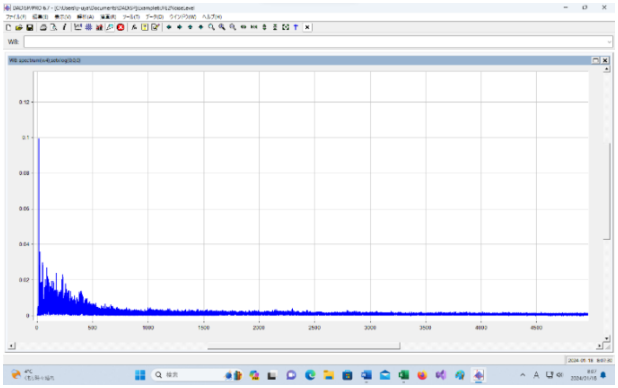


The graph determines the basic shape of the graph, since the component of 1 Hz has an unsurpassed sound pressure. Other components only give partial variation to the basic graph.

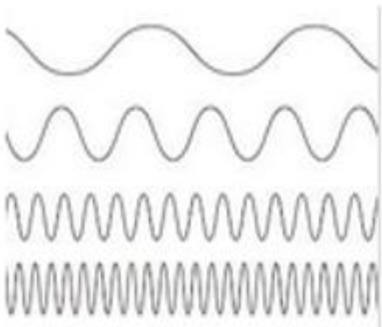


The overall graph and frequency spectrum of sound at JFE's factories are shown below.

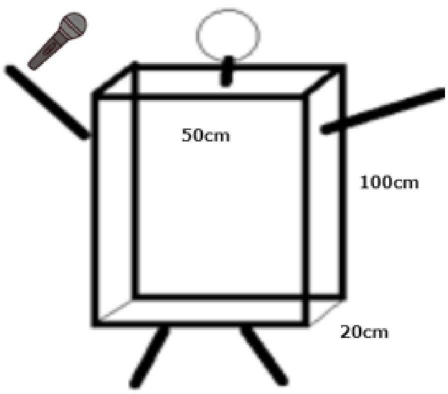


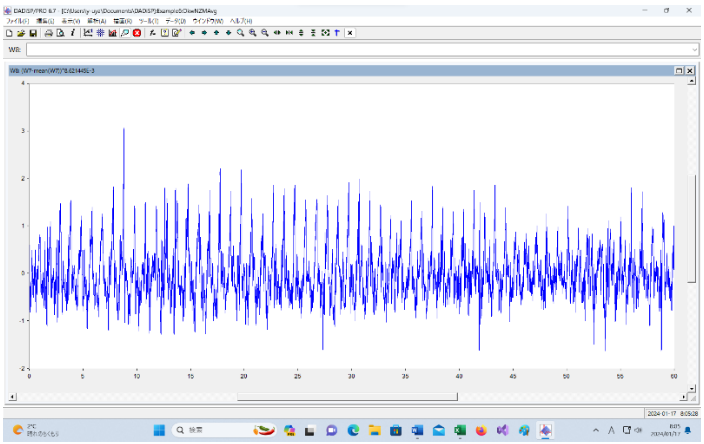


This difference in character affects the way in which the human body is pressed.



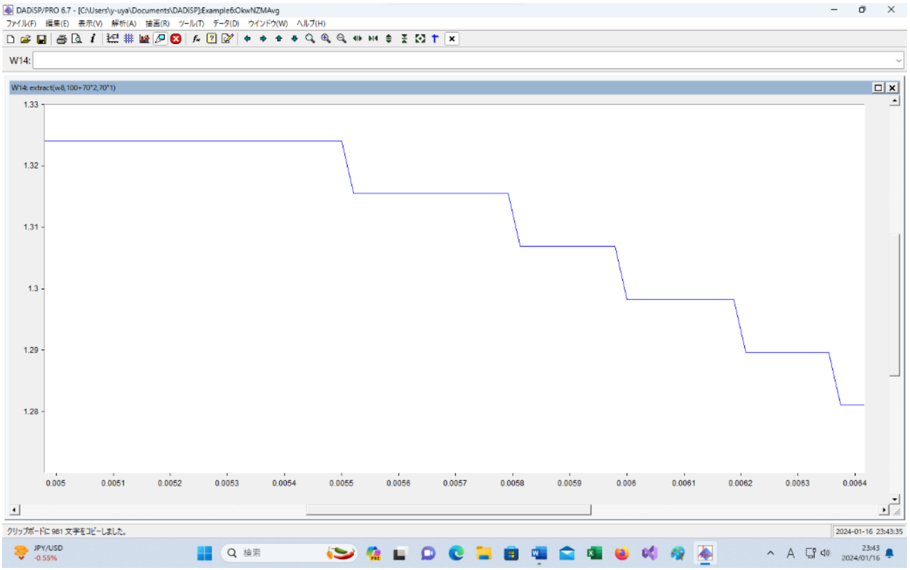
Suppose that sound of various wavelengths can reach a person from a windmill at a speed of 340 meters per second. Assuming a human width of 50 cm, a body length of 100 cm, and a thickness of 20 cm, the sound is a plane wave. Since the speed of sound is 340 m, it takes 0.5/340 seconds from the right side of the body to the left side of the body with the microphone. If the number of times the microphone measures sound pressure is 48000 times per second, then at 0.5/340 seconds, 48000 * 0.5/340 = 70.6 = 70 times.





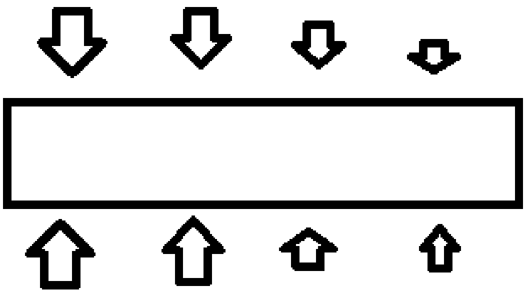
On the right is the measured windmill sound data. From now on, we will take out 70 pieces.

A graph of 70 consecutive numerical values of sound pressure



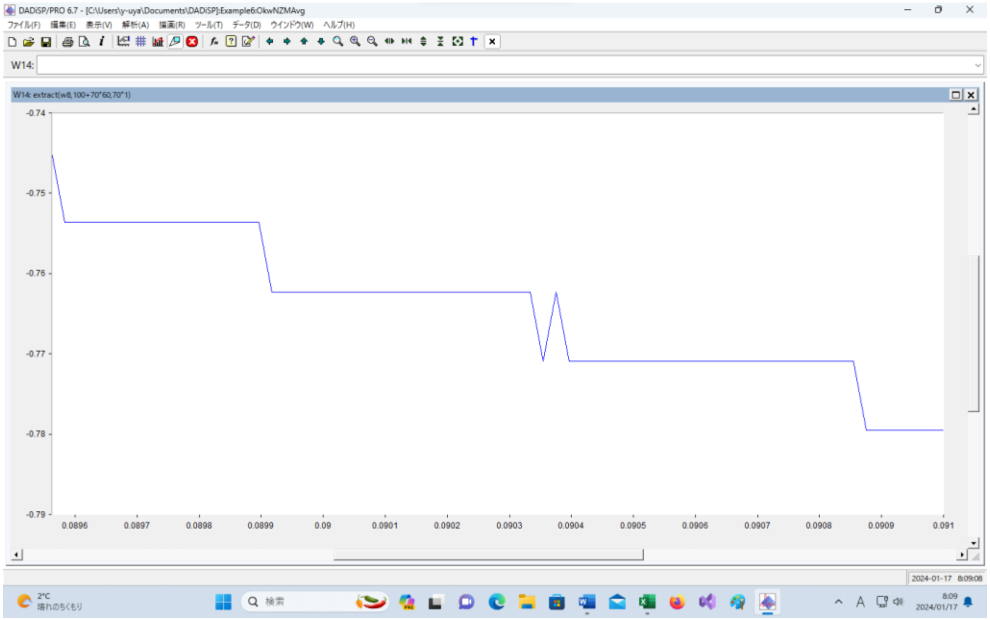
and the numerical value is

1.324106	1.324106	1.306864	1.289621
1.324106	1.324106	1.306864	1.289621
1.324106	1.324106	1.306864	1.289621
1.324106	1.324106	1.306864	1.289621
1.324106	1.324106	1.306864	1.289621
1.324106	1.324106	1.306864	1.289621
1.324106	1.315485	1.306864	1.289621
1.324106	1.315485	1.306864	1.280999
1.324106	1.315485	1.306864	1.280999
1.324106	1.315485	1.298242	1.280999
1.324106	1.315485	1.298242	
1.324106	1.315485	1.298242	
1.324106	1.315485	1.298242	
1.324106	1.315485	1.298242	
1.324106	1.315485	1.298242	
1.324106	1.315485	1.298242	合計
1.324106	1.315485	1.298242	91.74771
1.324106	1.315485	1.298242	
1.324106	1.315485	1.298242	平均
1.324106	1.315485	1.289621	1.310682



Total: 91 Pa, average: 1.3 Pa. At this time, the entire body is crushed.

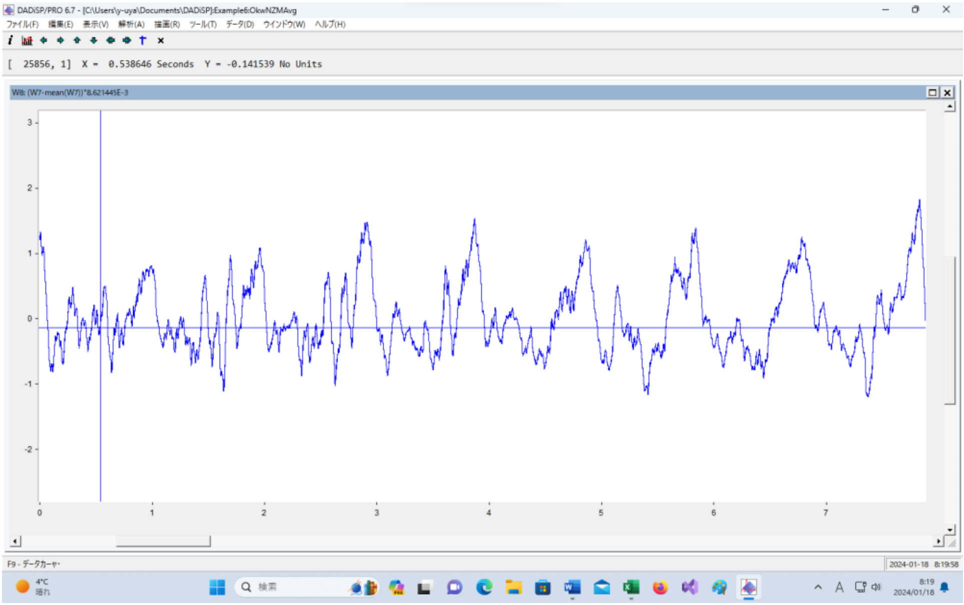
Of course



After a little while, it will be in a state of being pulled and inflated.

The value in the graph above is about -0.77 Pa. It is a state in which it is forcibly inflated.

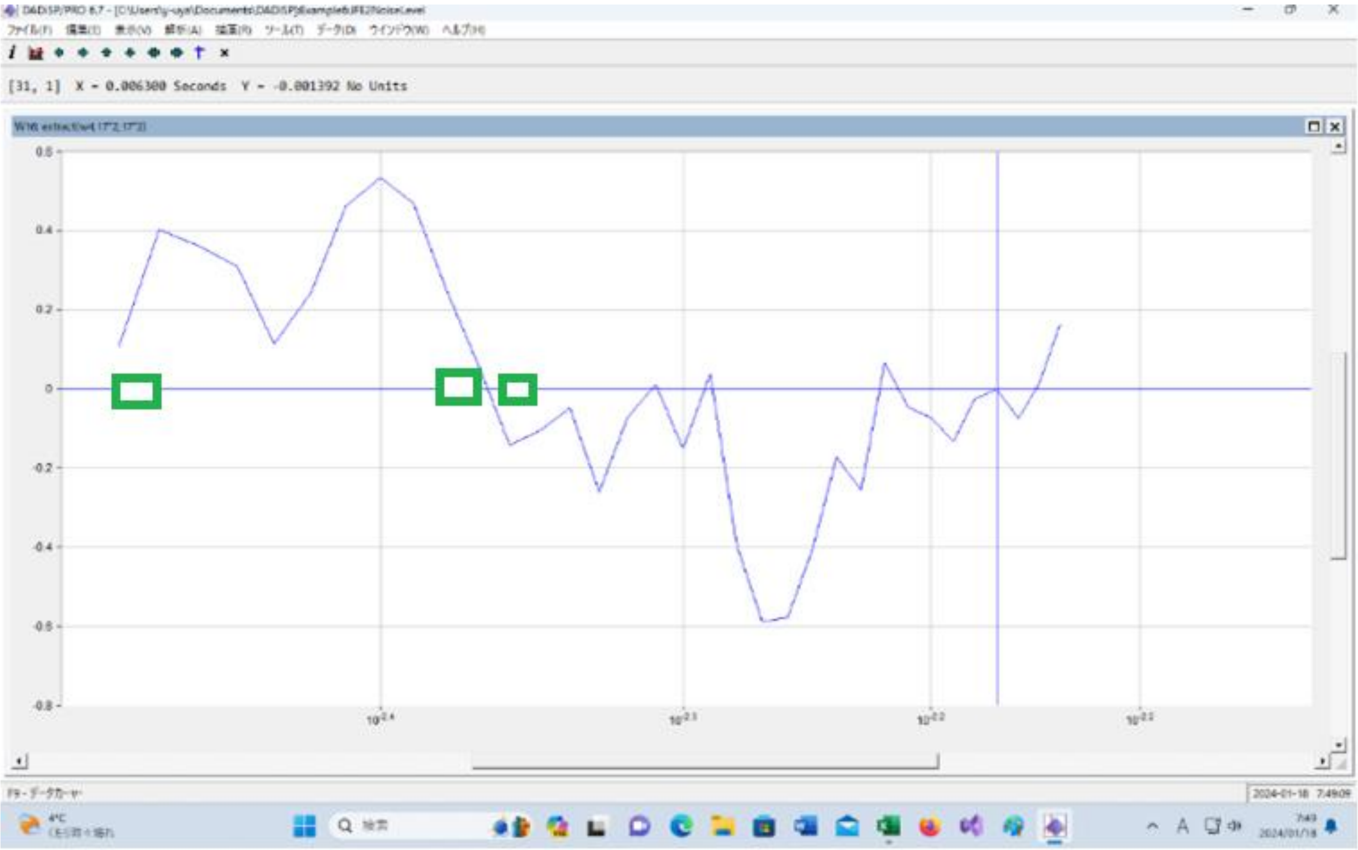
In the case of windmill sound, the following graph shows that the time it takes to compress the entire 50 cm is 0.5 seconds and the time to expand it is 0.5 seconds.



Rather than feeling pressure, the human body repeatedly compresses and expands every 0.5 seconds.

Physically, the pressure changes periodically.

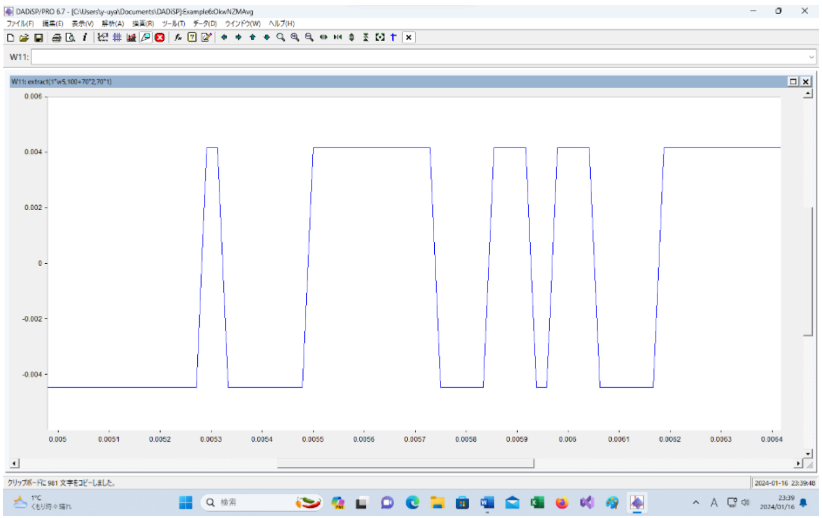
In the case of factory sound, the time required for a sound at 340 m/s to pass through 50 cm is 0.001 seconds. If you zoom in on the waveform for 0.002 seconds, you will get the following graph.



The duration of compression and expansion is about 0.04-2*0.001=0.038 seconds. Since the time is short, as soon as the skin starts exercising in compression, it starts the movement of swelling. Others have a mix of compression and expansion within a range of 50 cm.

The effect of pressure fluctuations in the body is considered to be minor.

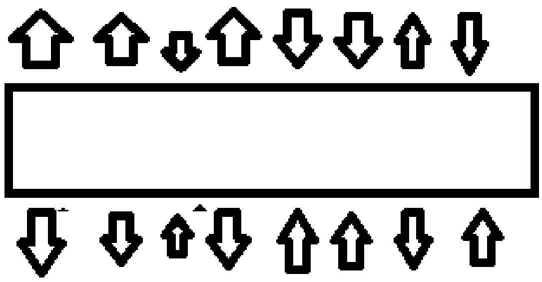
A graph of 70 consecutive numerical values of the sound pressure of sound at a shrine



and

The numeric value is

-0.00446		-0.00446		-0.00446		0.00416
-0.00446		-0.00446		-0.00446		0.00416
-0.00446		-0.00446		0.00416		0.00416
-0.00446		-0.00446		0.00416		0.00416
-0.00446		-0.00446		0.00416		0.00416
-0.00446		0.00416		0.00416		0.00416
-0.00446		0.00416		-0.00446		0.00416
-0.00446		0.00416		-0.00446		0.00416
-0.00446		0.00416		0.00416		0.00416
-0.00446		0.00416		0.00416		0.00416
-0.00446		0.00416		0.00416		
-0.00446		0.00416		0.00416		
-0.00446		0.00416		-0.00446		
-0.00446		0.00416		-0.00446		
-0.00446		0.00416		-0.00446		
0.00416		0.00416		-0.00446		合計
0.00416		0.00416		-0.00446		-0.01919
-0.00446		-0.00446		-0.00446		
-0.00446		-0.00446		0.00416		平均
-0.00446		-0.00446		0.00416		-0.00027



Total: -0.01919 Pa, average: -0.00027 Pa.

There is a mix of places where it is pushed and places where it is pulled, so it is not unilaterally crushed.
Over time, the mixed plus and minus situation doesn't change much.
The entire width of the windmill is pushed by the entire 50 cm width, but with the sound of the shrine, each part is pushed and pulled, so the overall effect is about 1/100.
In the case of a windmill (the sound of a special frequency is extremely strong), you may feel a sense of pressure, but if it has the properties of a shrine sound (it has many frequency components), you will not feel a sense of oppression.
Under the sound of windmills, the human body compresses and expands every 0.5 seconds, rather than feeling pressure.
The physical pressure on the human body changes periodically.
Among infrasound frequencies, those with an infrasound frequency of 1 Hz have an overwhelmingly high pressure, so the pressure fluctuation on the human body is determined by the period. This will not be the case if something with a frequency similar to this exists at a similar sound pressure. This is the most significant difference between windmill noise and other environmental noises.
The 164 measured windmill sounds also show that isolated frequencies around 0.5~1Hz have extremely high pressures than other frequencies. In the vicinity of all 164 measured windmills, the human body is subjected to forced, compressed and expanded.

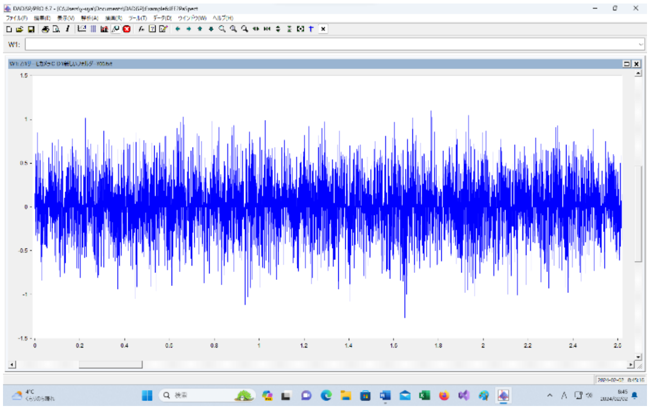
We will check further about compression, expansion.

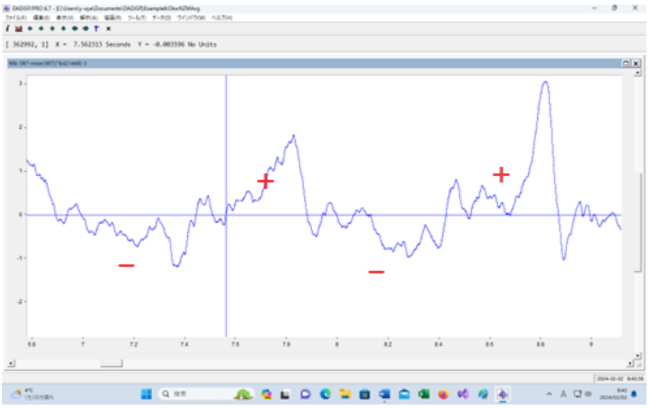
The sound of windmills changes depending on the wind speed. As the speed increases, the lift on the blades increases. The magnitude of the lift force is proportional to the square of the wind speed. This also changes the moment of rotation on the tower. As a result, the amplitude of the sides of the tower also increases. The sound pressure also changes.

When the wind is light, the sound pressure is 0.15 Pa, but when the wind is strong, it increases to 0.42 Pa. The fundamental frequency increases from 0.8 Hz to about 1.0 Hz.

The fluctuation of sound pressure is large, but the fluctuation of frequency is small.

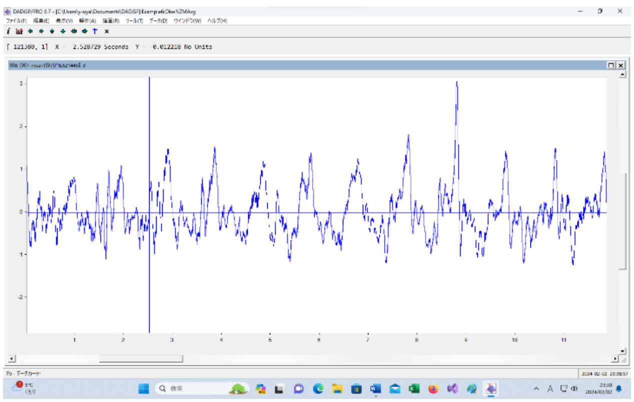
2.6 seconds waveform of factory noise 2.2 seconds waveform of windmill sound

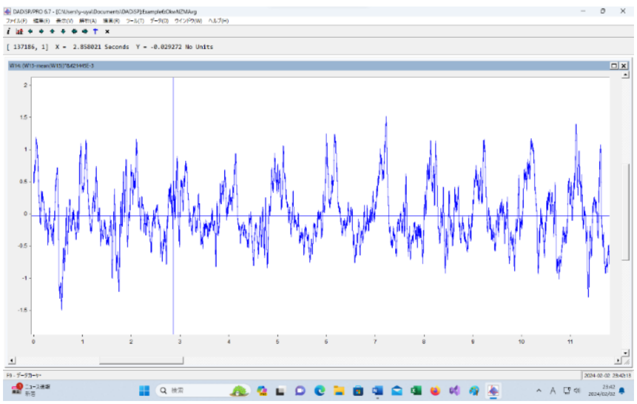




This is the cause of the slow repetition of compression and expansion.

12 seconds when the sound pressure is high (windy) 12 seconds when the sound pressure is low (wind is light)





When the wind is strong, the positive and negative sound pressure are clearer. In a stronger form, the process of compression and expansion will continue. We believe that directivity has a similar effect.

When it was windy, it was 0.42 Pa at 1 Hz. When the wind was light, it was 0.15 Pa and 0.8 Hz. The change in frequency is small, but the change in sound pressure is large.

From this, it can be seen that in multivariate analysis, it is good to set an item of (PT = maximum sound pressure * period).

対象	周波数[Hz]	周期[S]	最大音圧	PT
車（強）	1	1	0.42	0.42
箱（中）	1	1	0.33	0.33
外（弱）	1	1	0.23	0.23
穏かな日	0.8	1.25	0.15	0.1875
JFE	12.5	0.08	0.096	0.00768
神社	1	1	0.01	0.01

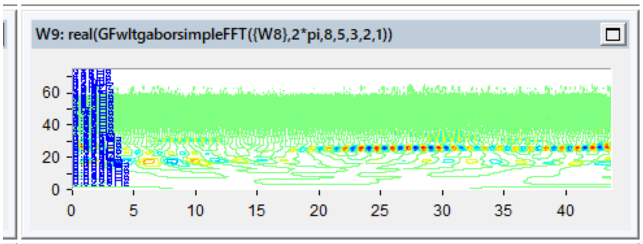
Symbol determination rate = maximum sound pressure / 2 番目の音圧

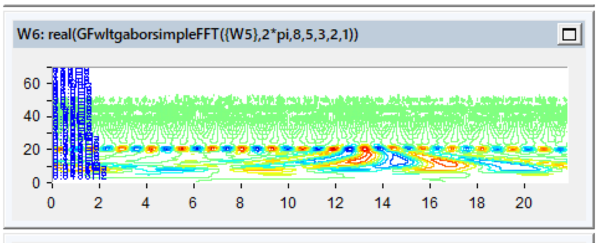
It would be better to put it on, but I'll put it on hold for now.

Furthermore, considering the effect of acoustic cavitation, it is more likely that the air dissolved in the body will precipitate and become a gas when the wind is strong. Air bubbles in the body are the same as diving sickness, so they can cause headaches.

Due to the directionality of the wind turbine sound and the drastic change in wind speed, the time to meet the conditions is usually about 20 seconds, but if the wind speed and direction are stable, the damage is considered to be large.

If you display the results of the windmill sound for 2 minutes side by side, it will look like the following.





It can be seen that the frequency component of about 0.8 Hz is emitted at a strength of about 0.3 Pascals for about 100 seconds. It is long enough to generate resonance, resonance phenomena, etc., and wake up a sleeping person.

In addition, the parts where the color is particularly dark will last for about 20 seconds. If this part continues, the effects at high sound pressure will be perceived. It's fine if it's just an effect that wakes you up, but if it's long, the more likely it is that bubbles will form.

If you refer to the "Bubble Engineering" Techno System,

11. Growth of air bubbles in the sound field

Under constant pressure, the bubbles disappear as long as the non-condensed gas is not supersaturated. On the other hand, even in the insufficiently saturated state of bubbles placed in the acoustic field, the growth of bubbles due to the precipitation of non-condensed gas can be seen. This phenomenon causes acoustic cavitation to occur, and is also used to promote the removal of dissolved gas in the liquid.

The amount of non-condensed gas precipitation in the bubbles is equation (5.5.55)

$$\frac{d}{dt}\left(\frac{4}{3}\pi R^3 \rho_g\right) = 4\pi R^2 D_{gL} \frac{\partial \rho_{gL}}{\partial r}\Big|_W \qquad (2.5.55)$$

By.

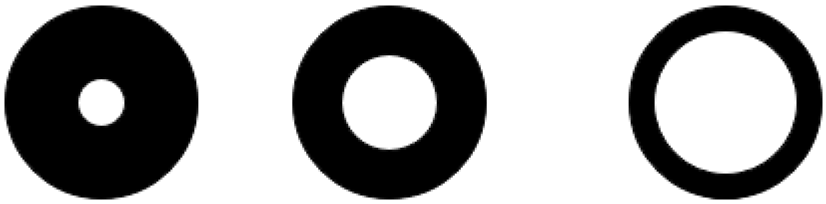
If the thickness of the concentration boundary layer in the liquid is used δ_D, the amount of gas precipitation and dissolution per unit period is

$$\dot{m}_g \propto R^2 \times (\rho_{gi0} - \rho_{giW}) / \delta_D \qquad (2.5.61)$$

Become.

Based on this, the mechanism of the phenomenon shown in Fig. 2.5.6 will be described.

Figure 2.5.6



収縮時	平衡時	膨張時
$p_g > p_{g0}$	p_{g0}	$p_g < p_{g0}$
$R < R_0$	R_0	$R > R_0$
$\delta_D > \delta_{D0}$	δ_{D0}	$\delta_D < \delta_{D0}$

First of all, the concentration of non-condensed gas in bubble surface liquids ρ_{gLW} is Henry's law

$$\rho_{gLW} = \alpha p_g \qquad (2.5.58)$$

According to the above, it rises and decreases with pressure fluctuations that contract and expand. During condensation when the concentration increases, the non-condensed gas in the bubble dissolves in the liquid, and during expansion when the concentration decreases, the gas precipitates into the bubble.

At this time, since the bubble surface area is larger during expansion, it is considered that the amount of precipitation is slightly superior when viewed in one cycle of expansion and contraction.

When the frequency of the sound wave is large, the diffusion of the gas dissolved in the liquid does not occur, so the growth of the bubble slows down.

When the frequency is small, when expanding, the gas in the liquid precipitates in the bubble, and the concentration of the gas around the bubble decreases. The concentration is restored by the diffusion of the gas dissolved in the liquid

before the contraction begins.
Contraction causes the gases in the bubble to dissolve into the surrounding solution. Since the concentration of dissolved gas in the surrounding liquid is not much reduced, the amount dissolved is small.
By repeating this process, it is thought that the bubbles grow more at low frequencies.
Next, the boundary layer of non-condensable gas concentration in the near-surface liquid becomes thinner when expanding and thicker during contraction. Considering that the mass transport by diffusion becomes more pronounced as the thickness of the boundary layer decreases, the amount of precipitation due to expansion exceeds the amount of dissolution due to contraction.

It has become.

In large wind turbines, the rotation speed R of the wind turbine is smaller. The maximum sound pressure is around 0.5 Hz. It is predicted that there will be an increase in physical ailments due to headaches and pressure caused by microscopic bubbles.

Among infrasound frequencies, those with an infrasound frequency of 1 Hz have an overwhelmingly high pressure, so the pressure fluctuation on the human body is determined by the period. This will not be the case if something with a frequency similar to this exists at a similar sound pressure. This is the most significant difference between windmill noise and other environmental noises.

We have already confirmed that the sound of the 164 measured windmills has an extremely high pressure compared to other frequencies in isolated frequencies around 0.5~1Hz. In the vicinity of all the measured windmills, the human body is subjected to forced, compressed and expanded.
This means that, considering the effects of acoustic cavitation, the air dissolved in the body may precipitate and become a gas. Air bubbles in the body cause headaches in the same way as diving sickness.
This is the direct health effect of the sound of windmills. This is a very physical cause and is caused by the frequency response of the windmill sound. This is an inevitable consequence of the fact that a wind turbine with a horizontal axis of rotation rotates due to the lifting force applied to the blades in the difference in wind speed between the sky and near the ground.

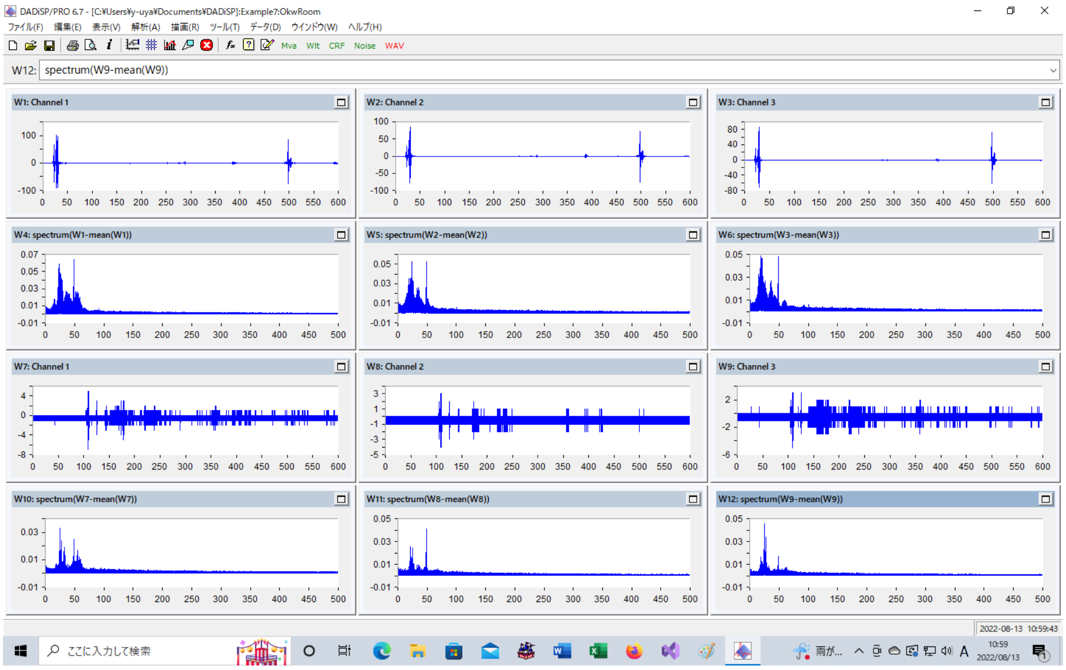
The physical structure of the windmill is the root cause of health problems.
Therefore, the horizontally axle windmill is the most defective product.
Laying them out at a distance of 2 km from land is madness.

Chapter 6 Vibration Analysis

6.1 Vibration in the room

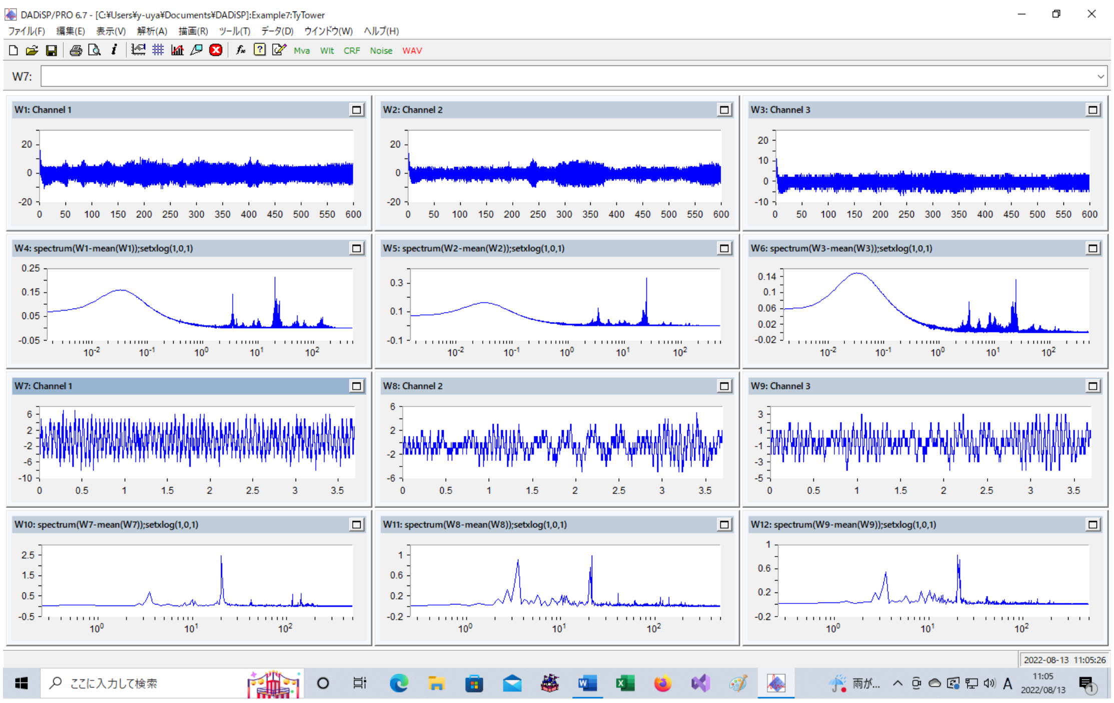
I measured the vibration in the room. Vibrations with an electrical frequency of 50 Hz can be seen.

OkwRoom

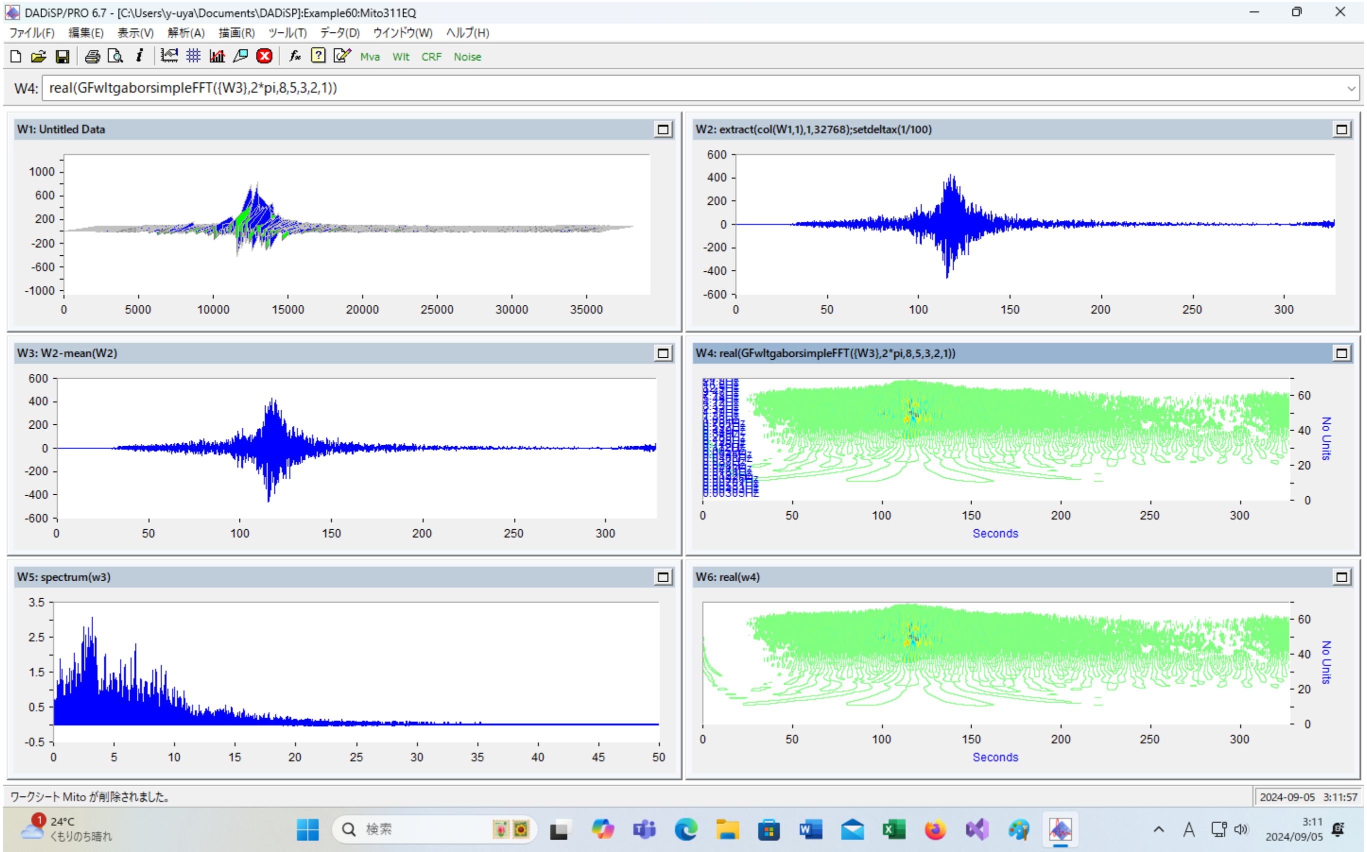


It is a vibration in the immediate vicinity of a wind-turbine. Vibrations with a frequency of 20 Hz to 30 Hz are noticeable.

TyTower



The shaking of the 2011 The Great East Japan Earthquake was measured in Mito City, Ibaraki Prefecture.
Mito311EQ



/**/

/* LA90 (2024.09.15)*/
LA90(NLVW,pc)

argument
NLVW； Graph showing the fluctuation of A-weighted sound pressure level
pc； percent

Functions of the function
pc=0: Returns the maximum value of the A-weighted sound pressure level.
pc=100: Returns the minimum value of the A-weighted sound pressure level.
0<pc<100: A collection of A-weighted sound pressure level values greater than k, that is the pc% of the Total, returns the value k.

Reference worksheets
T y4N L Vary

/* Energy Distribution (2024.08.29)*/
EngDistributionWm2(wpat,f1,f2,f3,f4)

argument
Wpat: Sound pressure data displayed in Pascal values. (The one with the window function multiplied.))
f1;start frequency
f2;intermediate frequency 1
f3;intermediate frequency2
f4;end frequency

Functions of the function
The energy of the passing sound is calculated for each frequency band and the whole.
Energy of frequency components up to f1~f2 Hz (W/㎡)
Energy of frequency components up to f2~f3 Hz (W/㎡)
Energy of frequency components up to f3~f4 Hz (W/㎡)
f1~f4 Hz overall energy (W/㎡)
Returns a table of

Reference worksheets
NzTyEngDist

/* PascalSquareSum (2024.08.29) */
PaSqsum(wpat,f1,f2)

argument
Wpat: Sound pressure data displayed in Pascal values. (The one with the window function multiplied.))
f1;start frequency
f2;end frequency

Functions of the function
From f1Hz, we take the frequency components up to f2Hz, square each value, and return the sum of them

Reference worksheets
NL42Sample

/***/

/* Filter (f1-f2) Make (2022.8.1) */
mkfilt(wpat,f1,f2)

argument
Wpat: Data displayed in Pascal values, multiplied by a window function.
f1;start frequency
f2;end frequency

Functions of the function
Create a filter to extract frequency components from f1Hz to f2Hz.

/***/

/* Filter (f1-f2) Apply (2022.8.1) */
apfilt(wpat,f1,f2)

argument
Wpat: Data displayed in Pascal values, multiplied by a window function.
f1;start frequency
f2;end frequency

Functions of the function

From f1Hz, the frequency components up to f2Hz are extracted.

Use a rectangular window to check whether the sum of the extracted low-frequency sound and the extracted high-frequency sound match the original data. (Do not use the window function)

Reference worksheets

JFE2Felt

/**/

/* Extention and shift of each column data */

shiext(md,coln,ext,shift)

argument

Md;matrix data

Column number (In DADISP, the column data is a line that extends horizontally across the graph.))

Ext;Magnification

Shift；移動量

/***/

/* Swish 1d3 A 20Hz (2022.6.23) (20Hz::20000Hz) */

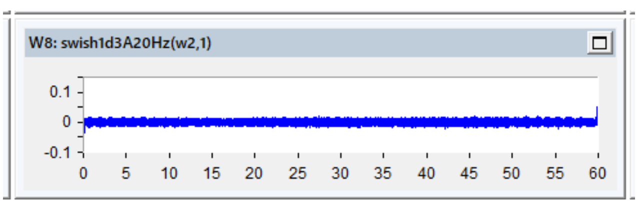
Swish1d3A20Hz(wpa,w)

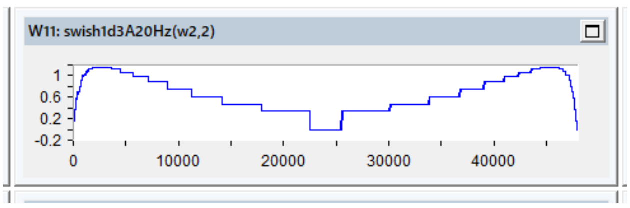
argument

WPA; Pascal value data

W; Optional (1 or 2)

If w=1 If w=2





Functions of the function

Calculate the FFT of the Wap and weight the result by the A characteristic using a graph when w=2. If the IFFT is calculated and returned to the original result, the noise evaluated according to the A characteristic (20 Hz or more) can be obtained.

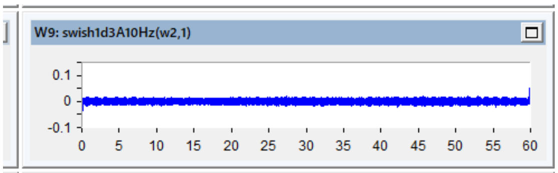
In this case, since the weighting of the A-weighting and the center frequency of the bandpass filter is greater than or equal to 20 Hz, components below 20 Hz are treated as 0.
As a result, it has the effect of creating a rectangular filter and extracting components from 200 Hz to 20 kHz. This shows the state of amplitude modulation in the audible range.

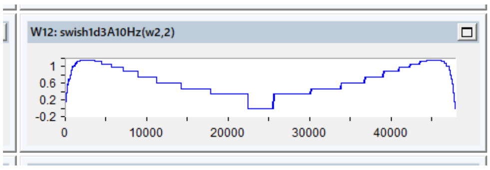
Reference worksheets
Ty4Swish

/***/

/* Swish 1d3 A 10Hz (2022.5.10) (10Hz::20000Hz) */
Swish1d3A10Hz(wpa,w)

argument
WPA; Pascal value data
W;Optional (1 or 2)
If w=1 If w=2





Functions of the function
Calculate the FFT of the Wap and weight the result by the A characteristic using a graph when w=2. If the IFFT is calculated and returned to the original result, the noise evaluated according to the A characteristic (10 Hz or more) can be obtained.
In this case, since the weighting of the A-weighting and the center frequency of the bandpass filter is greater than or equal to 10 Hz, components below 10 Hz are treated as 0.
As a result, it has the effect of creating a rectangular filter and extracting components from 200 Hz to 20 kHz. This shows the state of amplitude modulation in the audible range.

Reference worksheets
Ty4Swish

/***/

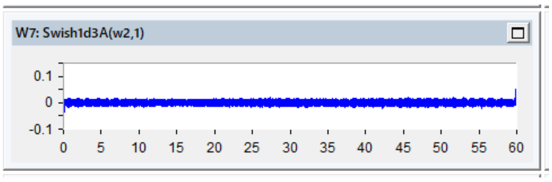
/* Swish 1d3 A (2022.5.10) IEC 1672:2014 (6.3Hz::20000Hz) */
Swish1d3A(wpa,w)

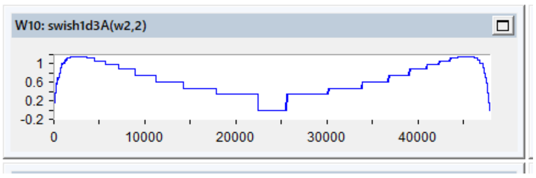
argument

WPA; Pascal value data

W;Optional (1 or 2)

If w=1 If w=2





Functions of the function

Calculate the FFT of the Wap and weight the result by the A characteristic using a graph when w=2. If the IFFT is calculated and returned to the original result, the noise evaluated according to the A characteristic (6.8 Hz or higher) can be obtained.

In this case, since the weighting of the A weighting and the center frequency of the bandpass filter are greater than or equal to 6.8 Hz, components below 6.8 Hz are treated as 0.

As a result, it has the effect of creating a rectangular filter and extracting components from 200 Hz to 20 kHz. This shows the state of amplitude modulation in the audible range.

Reference worksheets

Ty4Swish

/**/

/* AVGLAeq20HzSqHanning (2022.7.23) */

AVGLAeq20HzSqHn(wpa,nn,w)

argument

WPA; Pascal value data

Nn;平均を取る回数

W;Optional (1 or 2)

Functions of the function

If w=1

Divide the data wpa of Pascal values into nn pieces. While using a Hanning window for each divided data, the A-weighted sound pressure level is determined by weighting from 2 0 Hz$L_{20,A,n}$.

$$L_{20,A,n} = 20 * log10(\frac{P_{20,A,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{20,A,n}$

$(P_{20,A,T})\hat{}2 = ((P_{20,A,1})\hat{}2 + (P_{20,A,2})\hat{}2 + \cdots + (P_{20,A,nn})\hat{}2)/nn$

It becomes, from,$P_{20,A,T}$

$$L_{20,A,T} = 20 * log_{10}(\frac{P_{20,A,T}}{0.00002})$$

and return this value.

The formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

It is a calculation close to that.

If w=2

Divide the data wpa of Pascal values into nn pieces. For each divided data, use the Hanning window to calculate spectrum(), cut out the components in the range of frequencies (20Hz~20kHz) handled by weighting from 20Hz, and obtain the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers.$P_{20,p,T}$

$$L_{20,P,T} = 20 * log_{10}(\frac{P_{20,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets
AVGLAeqSq

/***/

/* AVGLAeq10HzSqHanning (2022.7.23) */
AVGLAeq10HzSqHn(wpa,nn,w)

argument
WPA; Pascal value data
Nn;平均を取る回数
W;Optional (1 or 2)

Functions of the function
If w=1

Divide the data wpa of Pascal values into nn pieces. While using a Hanning window for each divided data, the A-weighted sound pressure level is determined by weighting from 10 Hz.$L_{10,A,n}$

$$L_{10,A,n} = 20 * log10(\frac{P_{10,A,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{20,A,n}$

$(P_{10,A,T})^\wedge 2 = ((P_{10,A,1})^\wedge 2 + (P_{10,A,2})^\wedge 2 + \cdots + (P_{10,A,nn})^\wedge 2)/nn$

It becomes, from,$P_{10,A,T}$

$$L_{10,A,T} = 20 * log_{10}(\frac{P_{10,A,T}}{0.00002})$$

and return this value.

The formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} / P_0\right\}$$

It is a calculation close to that.

If w=2

Divide the data wpa of Pascal values into nn pieces. For each divided data, use the Hanning window to calculate spectrum(), cut out the components in the range of frequencies (10Hz~20kHz) in the range handled by weighting from 10Hz, and obtain the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers.$P_{10,p,T}$

$$L_{10,P,T} = 20 * log_{10}(\frac{P_{10,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets

AVGLAeqSq

/***/

/* AVGLAeqSqHanning (2022.7.23) */

AVGLAeqSqHn(wpa,nn,w)

argument

WPA; Pascal value data

Nn;平均を取る回数

W;Optional (1 or 2)

Functions of the function

If w=1

Divide the data wpa of Pascal values into nn pieces. While using a Hanning window for each divided data, the A-weighted sound pressure level is determined by weighting from 6.3 Hz.$L_{63,A,n}$

$$L_{63,A,n} = 20 * log10(\frac{P_{63,A,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{63,A,n}$

$(P_{63,A,T})^2 = ((P_{63,A,1})^2 + (P_{63,A,2})^2 + \cdots + (P_{63,A,nn})^2)/nn$

It becomes, from,$P_{63,A,T}$

$$L_{63,A,T} = 20 * log_{10}(\frac{P_{63,A,T}}{0.00002})$$

and return this value.

The formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

It is a calculation close to that.

If w=2

Divide the data wpa of Pascal values into nn pieces. For each divided data, use the Hanning window to calculate spectrum(), cut out the components in the range of frequencies (6.3Hz~20kHz) handled by weighting from 6.3Hz, and obtain the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers.$P_{63,p,T}$

$$L_{63,P,T} = 20 * log_{10}(\frac{P_{63,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets

AVGLAeqSq

/***/

/* AVGLGeq7196SqHanning (2022.7.23) */

AVGLGeq7196SqHn(wpa,nn,w)

argument

WPA; Pascal value data

Nn;平均を取る回数

W;Optional (1 or 2)

Functions of the function

If w=1

Divide the data wpa of Pascal values into nn pieces. While using the Hanning window for each divided data, the G-weighted sound pressure level is determined by weighting from 0.25 Hz$L_{25,G,n}$.

$$L_{25,G,n} = 20 * log10(\frac{P_{25,G,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{25,A,n}$

$(P_{25,G,T})$^2 $= ((P_{25,G,1})$^2 $+ (P_{25,G,2})$^2 $+ \cdots + (P_{25,G,nn})^2)/nn$

It becomes, from,$P_{25,G,T}$

$$L_{25,G,T} = 20 * log_{10}(\frac{P_{25,G,T}}{0.00002})$$

and return this value.

The following equation in the manual of the NL-62 of the company of Lion changed A to G

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} / P_0\right\}$$

It is a calculation close to that.

If w=2

Divide the data wpa of Pascal values into nn pieces. For each divided data, use the Hanning window to calculate spectrum(), cut out the components in the range of frequencies (0.25Hz ~ 315Hz) handled by weighting from 0.25Hz, and obtain the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers.$P_{63,p,T}$

$$L_{25,P,T} = 20 * log_{10}(\frac{P_{25,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets

AVGLGeqSq

/**/

/* AVGLGeqSqHanning (2022.7.23) */

AVGLGeqSqHn(wpa,nn,h,w)

argument

WPA; Pascal value data

Nn;平均を取る回数

h;A number between 0 and 1 that determines the lower frequency limit of a bandpass filter with a center frequency of 1 Hz.

W;Optional (1 or 2)

Functions of the function

h;When the value of h is between the lower frequency of the band with a center frequency of 1 Hz and 0, the lower limit of this bandpass filter

The frequency is changed to h.

If w=1

Divide the data wpa of Pascal values into nn pieces. While using the Hanning window for each of the divided data, the G-weighted sound pressure level is determined by weighting from 1 Hz.$L_{1,G,n}$

$$L_{1,G,n} = 20 * log10(\frac{P_{1,G,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{1,G,n}$

$(P_{1,G,T})^2 = ((P_{1,G,1})^2 + (P_{1,G,2})^2 + \cdots + (P_{1,G,nn})^2)/nn$

It becomes, from,$P_{1,G,T}$

$$L_{1,G,T} = 20 * log_{10}(\frac{P_{1,G,T}}{0.00002})$$

and return this value.

リオン社の NL-62 のマニュアルにある次の式でAをGに変えたもの

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N}P_A^2(i)\right)^{\frac{1}{2}}/P_0\right\}$$

に近い計算となる。

If w=2

Divide the data wpa of Pascal values into nn pieces. For each divided data, we calculate spectrum() while using the Hanning window, cut out the components in the range of frequencies (1Hz~80Hz) in the range handled by weighting from 1Hz, and obtain the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers.$P_{1,p,T}$

$$L_{1,P,T} = 20 * log_{10}(\frac{P_{1,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets

AVGLGeqSq

/***/

/* AVGLAeq20HzHanning (2022.7.23) */

AVGLAeq20HzHn(wpa,nn,w)

argument
WPA; Pascal value data
Nn;平均を取る回数
W;Optional (1 or 2)

Functions of the function
If w=1
Divide the data wpa of Pascal values into nn pieces. While using a hanning window for each divided data, the A-weighted sound pressure level is determined by weighting from 20 Hz. $L_{20,A,n}$Returns $L_{20,A,n}$the additive mean of NN

The calculation method is different, but the formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N}P_A^2(i)\right)^{\frac{1}{2}}/P_0\right\}$$

It is close to the value of.

If w=2
Divide the data wpa of Pascal values into nn pieces. For each divided data, use the Hanning window to calculate spectrum(), cut out the components in the range of frequencies (20Hz ~ 20kHz) handled by weighting from 20Hz, obtain the sound pressure level by nn with the weight as 0, and return the additive average.

Reference worksheets
AVGLAeq

/**/

/* AVGLAeq10HzHanning (2022.7.23) */
AVGLAeq10HzHn(wpa,nn, w)

argument
WPA; Pascal value data
Nn;平均を取る回数
W;Optional (1 or 2)

Functions of the function
If w=1
Divide the data wpa of Pascal values into nn pieces. While using a Hanning window for each divided data, the A-weighted sound pressure level is determined by weighting from 10 Hz. $L_{10,A,n}$Returns $L_{10,A,n}$the additive mean of NN

The calculation method is different, but the formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N}P_A^2(i)\right)^{\frac{1}{2}}/P_0\right\}$$

It is close to the value of.

If w=2

Divide the data wpa of Pascal values into nn pieces. For each divided data, use the Hanning window to calculate spectrum(), cut out the components in the range of frequencies (10Hz ~ 20kHz) handled by weighting from 10Hz, find the sound pressure level by nn with the weight as 0, and return the additive average.

Reference worksheets
AVGLAeq

/**/

/* AVGLAeqHanning (2022.7.23) */
AVGLAeqHn(wpa,nn,h)

argument
WPA; Pascal value data
Nn;平均を取る回数
W;Optional (1 or 2)

Functions of the function
If w=1

Divide the data wpa of Pascal values into nn pieces. While using a Hanning window for each divided data, the A-weighted sound pressure level is determined by weighting from 6.3 Hz$L_{63,A,n}$. Returns $L_{63,A,n}$the additive mean of NN

The calculation method is different, but the formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N}P_A^2(i)\right)^{\frac{1}{2}}/P_0\right\}$$

It is close to the value of.

If w=2

Divide the data wpa of Pascal values into nn pieces. For each divided data, use the Hanning window to calculate spectrum(), cut out the components in the range of frequencies (6.3Hz ~ 20kHz) handled by weighting from 6.3Hz, obtain the sound pressure level by nn with a weight of 0, and return the additive average.

Reference worksheets
AVGLAeq

/***/

/* AVGLGeq7196Hanning (2022.7.23) */
AVGLGeq7196Hn(wpa,nn,w)

argument
WPA; Pascal value data
Nn;平均を取る回数
W;Optional (1 or 2)

Functions of the function
If w=1
Divide the data wpa of Pascal values into nn pieces. While using the Hanning window for each divided data, the G-weighted sound pressure level is determined by weighting from 0.25 Hz$L_{25,G,n}$. Returns $L_{25,G,n}$the additive mean of NN

The calculation method is different, but the following formula in the manual of the NL-62 of the company of Lion changed A to G

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N}P_A^2(i)\right)^{\frac{1}{2}}/P_0\right\}$$

It is close to the value of.

If w=2
Divide the data wpa of Pascal values into nn pieces. For each divided data, use the Hanning window to calculate spectrum(), cut out the components in the range of frequencies (0.25Hz ~ 315Hz) handled by weighting from 0.25Hz, obtain the sound pressure level by nn with a weight of 0, and return the additive average.

Reference worksheets
AVGLGeq

/***/

/* AVGLGeqHanning (2022.7.23) */
AVGLGeqHn(wpa,nn,h,w)

argument

WPA; Pascal value data

Nn;平均を取る回数

h;A number between 0 and 1 that determines the lower frequency limit of a bandpass filter with a center frequency of 1 Hz.

W;Optional (1 or 2)

Functions of the function

h;When the value of h is between the lower frequency of the band with a center frequency of 1 Hz and 0, the lower limit of this bandpass filter

The frequency is changed to h.

If w=1

Divide the data wpa of Pascal values into nn pieces. Using the Hanning window for each of the divided data, the G-weighted sound pressure level is determined by weighting from 1 Hz, and$L_{1,G,n}$ $L_{1,G,n}$the additive average of n n is returned.

The following equation in the manual of the NL-62 of the company of Lion changed A to G

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

It will be close to the value.

If w=2

Divide the data wpa of Pascal values into nn pieces. For each divided data, while using the Hanning window, spectrum() is calculated, the components in the range of frequencies (1Hz ~ 80Hz) handled by weighting from 1Hz are cut out, the weight is 0, the sound pressure level is obtained by nn, and the additive average is returned.

Reference worksheets

AVGLGeq

/**/

/* AVGLAeq20HzSqFlattop (2022.7.23) */

AVGLAeq20HzSqFt(wpa,nn,w)

argument

WPA; Pascal value data

Nn;平均を取る回数

W;Optional (1 or 2)

Functions of the function

If w=1

Divide the data wpa of Pascal values into nn pieces. While using a flat-top window for each divided data, the A-weighted sound pressure level is determined by weighting from 20 Hz.$L_{20,A,n}$

$$L_{20,A,n} = 20 * log10(\frac{P_{20,A,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{20,A,n}$

$(P_{20,A,T})$^2 $= ((P_{20,A,1})$^2 $+ (P_{20,A,2})$^2 $+ \cdots + (P_{20,A,nn})^2)/nn$

It becomes, from,$P_{20,A,T}$

$$L_{20,A,T} = 20 * log_{10}(\frac{P_{20,A,T}}{0.00002})$$

and return this value.

The formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} / P_0\right\}$$

It is a calculation close to that.

If w=2

Divide the data wpa of Pascal values into nn pieces. Using a flat-top window for each divided data, we calculate spectrum(), cut out the components in the range of frequencies (20Hz~20kHz) handled by weighting from 20Hz, and obtain the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers.$P_{20,p,T}$

$$L_{20,P,T} = 20 * log_{10}(\frac{P_{20,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets

AVGLAeqSq

/***/

/* AVGLAeq10HzSqFlattop (2022.7.23) */

AVGLAeq10HzSqFt(wpa,nn,w)

argument

WPA; Pascal value data

Nn; 平均を取る回数

W; Optional (1 or 2)

Functions of the function

If w=1

Divide the data wpa of Pascal values into nn pieces. While using a flat-top window for each of the divided data, the A-weighted sound pressure level is determined by weighting from 10 Hz.$L_{10,A,n}$

$$L_{10,A,n} = 20 * log10(\frac{P_{10,A,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{20,A,n}$

$(P_{10,A,T})$^2 $= ((P_{10,A,1})$^2 $+ (P_{10,A,2})$^2 $+ \cdots + (P_{10,A,nn})^2)/nn$

It becomes, from,$P_{10,A,T}$

$$L_{10,A,T} = 20 * log_{10}(\frac{P_{10,A,T}}{0.00002})$$

and return this value.

The formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} / P_0\right\}$$

It is a calculation close to that.

If w=2

Divide the data wpa of Pascal values into nn pieces. While using a flat-top window for each divided data, calculate spectrum(), cut out the components in the range of frequencies (10Hz~20kHz) handled by weighting from 10Hz, and obtain the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers.$P_{10,p,T}$

$$L_{10,P,T} = 20 * log_{10}(\frac{P_{10,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets

AVGLAeqSq

/**/

/* AVGLAeqSqFlattop (2022.7.23) */

AVGLAeqSqFt(wpa,nn,w)

argument

WPA; Pascal value data

Nn;平均を取る回数

W;Optional (1 or 2)

Functions of the function

If w=1

Divide the data wpa of Pascal values into nn pieces. While using a flat-top window for each of the divided data, the A-weighted sound pressure level is determined by weighting from 6.3 Hz.$L_{63,A,n}$

$$L_{63,A,n} = 20 * log10(\frac{P_{63,A,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{63,A,n}$

$(P_{63,A,T})\hat{}2 = ((P_{63,A,1})\hat{}2 + (P_{63,A,2})\hat{}2 + \cdots + (P_{63,A,nn})\hat{}2)/nn$

It becomes, from,$P_{63,A,T}$

$$L_{63,A,T} = 20 * log_{10}(\frac{P_{63,A,T}}{0.00002})$$

and return this value.

The formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

It is a calculation close to that.

If w=2

Divide the data wpa of Pascal values into nn pieces. Using a flat-top window for each divided data, we calculate spectrum() to extract the components in the range of frequencies (6.3Hz~20kHz) that are handled by weighting from 6.3Hz, and obtain the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers.$P_{63,p,T}$

$$L_{63,P,T} = 20 * log_{10}(\frac{P_{63,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets

AVGLAeqSq

/**/

/* AVGLGeq7196SqFlattop (2022.7.23) */

AVGLGeq7196SqFt(wpa,nn,w)

argument

WPA; Pascal value data

Nn;平均を取る回数

W;Optional (1 or 2)

Functions of the function

If w=1

Divide the data wpa of Pascal values into nn pieces. While using a flat-top window for each of the divided data, the G-weighted sound pressure level is determined by weighting from 0.25 Hz$L_{25,G,n}$.

$$L_{25,G,n} = 20 * log10(\frac{P_{25,G,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{25,A,n}$

$(P_{25,G,T})^2 = ((P_{25,G,1})^2 + (P_{25,G,2})^2 + \cdots + (P_{25,G,nn})^2)/nn$

It becomes, from,$P_{25,G,T}$

$$L_{25,G,T} = 20 * log_{10}(\frac{P_{25,G,T}}{0.00002})$$

and return this value.

The following equation in the manual of the NL-62 of the company of Lion changed A to G

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

It is a calculation close to that.

If w=2

Divide the data wpa of Pascal values into nn pieces. Using a flat-top window for each divided data, we calculate spectrum(), cut out the components in the range of frequencies (0.25Hz~315Hz) that are handled by weighting from 0.25Hz, and obtain the sum of their squares. Let be the square root of the additive mean of the obtained nn numbers.$P_{63,p,T}$

$$L_{25,P,T} = 20 * log_{10}(\frac{P_{25,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets

AVGLGeqSq

/**/

/* AVGLGeqSqFlattop (2022.7.23) */

AVGLGeqSqFt(wpa,nn,h,w)

argument

WPA; Pascal value data

Nn;平均を取る回数

h;A number between 0 and 1 that determines the lower frequency limit of a bandpass filter with a center frequency of 1 Hz.

W;Optional (1 or 2)

Functions of the function

h;When the value of h is between the lower frequency of the band with a center frequency of 1 Hz and 0, the lower limit of this bandpass filter

The frequency is changed to h. When h=1, the original lower frequency limit remains the same.

If w=1

Divide the data wpa of Pascal values into nn pieces. While using a flat-top window for each of the divided data, the G-weighted sound pressure level is determined by weighting from 1 Hz$L_{1,G,n}$.

$$L_{1,G,n} = 20 * log10(\frac{P_{1,G,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{1,G,n}$

$(P_{1,G,T})^2 = ((P_{1,G,1})^2 + (P_{1,G,2})^2 + \cdots + (P_{1,G,nn})^2)/nn$

It becomes, from,$P_{1,G,T}$

$$L_{1,G,T} = 20 * log_{10}(\frac{P_{1,G,T}}{0.00002})$$

and return this value.

The following equation in the manual of the NL-62 of the company of Lion changed A to G

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

It is a calculation close to that.

If w=2

Divide the data wpa of Pascal values into nn pieces. Using a flat-top window for each of the divided data, we calculate spectrum(), cut out the components in the range of frequencies (1Hz~80Hz) in the range handled by weighting from 1Hz, and obtain the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers.$P_{1,p,T}$

$$L_{1,P,T} = 20 * log_{10}(\frac{P_{1,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets

AVGLGeqSq

/**/

/* AVGLAeq20HzFlattop (2022.7.23) */
AVGLAeq20HzFt(wpa,nn,h)

argument
WPA; Pascal value data
Nn;平均を取る回数
W;Optional (1 or 2)

Functions of the function
If w=1
Divide the data wpa of Pascal values into nn pieces. While using a flat-top window for each divided data, the A-weighted sound pressure level is determined by weighting from 20 Hz. $L_{20,A,n}$Returns $L_{20,A,n}$the additive mean of NN

The calculation method is different, but the formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N}P_A^2(i)\right)^{\frac{1}{2}}/P_0\right\}$$

It is close to the value of.

If w=2
Divide the data wpa of Pascal values into nn pieces. While using a flat-top window for each divided data, spectrum() is calculated, components in the range of frequencies (20Hz ~ 20kHz) handled by weighting from 20Hz are extracted, the weight is 0, the sound pressure level is obtained by nn, and the additive average is returned.

Reference worksheets
AVGLAeq

/**/

/* AVGLAeq10HzFlattop (2022.7.23) */
AVGLAeq10HzFt(wpa,nn,h)

argument
WPA; Pascal value data
Nn;平均を取る回数

W;Optional (1 or 2)

Functions of the function

If w=1

Divide the data wpa of Pascal values into nn pieces. While using a flat-top window for each of the divided data, the A-weighted sound pressure level is determined by weighting from 10 Hz. $L_{10,A,n}$Returns $L_{10,A,n}$the additive mean of NN

The calculation method is different, but the formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N}P_A^2(i)\right)^{\frac{1}{2}}/P_0\right\}$$

It is close to the value of.

If w=2

Divide the data wpa of Pascal values into nn pieces. Using a flat-top window for each divided data, s pectrum() is calculated, and the components in the range of frequencies (10Hz ~ 20kHz) handled by weighting from 10Hz are extracted, the weight is 0, the sound pressure level is obtained by nn, and the additive average is returned.

Reference worksheets

AVGLAeq

/***/

/* AVGLAeqFlattop (2022.7.23) */

AVGLAeqFt(wpa,nn,h)

argument

WPA; Pascal value data

Nn;平均を取る回数

W;Optional (1 or 2)

Functions of the function

If w=1

Divide the data wpa of Pascal values into nn pieces. While using a flat-top window for each of the divided data, the A-weighted sound pressure level is determined by weighting from 6.3 Hz$L_{63,A,n}$. Returns $L_{63,A,n}$the additive mean of NN

The calculation method is different, but the formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N}P_A^2(i)\right)^{\frac{1}{2}}/P_0\right\}$$

It is close to the value of.

If w=2

Divide the data wpa of Pascal values into nn pieces. Using a flat-top window for each divided data, s pectrum() is calculated, components in the range of frequencies (6.3Hz ~ 20kHz) handled by weighting from 6.3Hz are extracted, the weight is 0, the sound pressure level is obtained by nn, and the additive average is returned.

Reference worksheets

AVGLAeq

/***/

/* AVGLGeqFlattop (2022.7.23) */

AVGLGeq7196Ft(wpa,nn,h)

argument

WPA; Pascal value data

Nn;平均を取る回数

W;Optional (1 or 2)

Functions of the function

If w=1

Divide the data wpa of Pascal values into nn pieces. While using a flat-top window for each of the divided data, the G-weighted sound pressure level is determined by weighting from 0.25 Hz$L_{25,G,n}$. Returns $L_{25,G,n}$the additive mean of NN

The calculation method is different, but the following formula in the manual of the NL-62 of the company of Lion changed A to G

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N}P_A^2(i)\right)^{\frac{1}{2}}/P_0\right\}$$

It is close to the value of.

If w=2

Divide the data wpa of Pascal values into nn pieces. Using a flat-top window for each divided data, s pectrum() is calculated, and the components in the range of frequencies (0.25Hz ~ 315Hz) handled by weighting from 0.25Hz are cut out, the weight is set to 0, the sound pressure level is obtained by nn, and the additive average is returned.

Reference worksheets
AVGLGeq

/**/

/* AVGLGeqFlattop (2022.7.23) */
AVGLGeqFt(wpa,nn,h,w)

argument
WPA; Pascal value data
Nn;平均を取る回数
h;A number between 0 and 1 that determines the lower frequency limit of a bandpass filter with a center frequency of 1 Hz.
W;Optional (1 or 2)

Functions of the function
h;When the value of h is between the lower frequency of the band with a center frequency of 1 Hz and 0, the lower limit of this bandpass filter
The frequency is changed to h.

If w=1
Divide the data wpa of Pascal values into nn pieces. While using a flat-top window for each of the divided data, the G-weighted sound pressure level is determined by weighting from 1 Hz, and$L_{1,G,n}$ an $L_{1,G,n}$additive average of n n is returned.
The following equation in the manual of the NL-62 of the company of Lion changed A to G

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

It will be close to the value.

If w=2
Divide the data wpa of Pascal values into nn pieces. While using a flat-top window for each divided data, spectrum() is calculated, the components in the range of frequencies (1Hz ~ 80Hz) handled by weighting from 1Hz are cut out, the weight is 0, the sound pressure level is obtained by nn, and the additive average is returned.

Reference worksheets
AVGLGeq

/***/

/* AVGLAeq20HzSqHm (2022.7.17) */
AVGLAeq20HzSqHm(wpa,nn,w)

argument
WPA; Pascal value data
Nn;平均を取る回数
W;Optional (1 or 2)

Functions of the function
If w=1
Divide the data wpa of Pascal values into nn pieces. While using a humming window for each divided data, the A-weighted sound pressure level is determined by weighting from 20 Hz.$L_{20,A,n}$

$$L_{20,A,n} = 20 * log10(\frac{P_{20,A,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{20,A,n}$

$(P_{20,A,T})$^2 $= ((P_{20,A,1})$^2 $+ (P_{20,A,2})$^2 $+ \cdots + (P_{20,A,nn})^2)/nn$

It becomes, from,$P_{20,A,T}$

$$L_{20,A,T} = 20 * log_{10}(\frac{P_{20,A,T}}{0.00002})$$

and return this value.

The formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

It is a calculation close to that.

If w=2
Divide the data wpa of Pascal values into nn pieces. Using a Hamming window for each divided data, we calculate s pectrum(), cuts out the components in the range of frequencies (20Hz~20kHz) handled by weighting from 20Hz, and finds the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers. $P_{20,p,T}$

$$L_{20,P,T} = 20 * log_{10}(\frac{P_{20,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets

AVGLAeqSq

/**/

/* AVGLAeq10HzSqHm (2022.7.17) */
AVGLAeq10HzSqHm(wpa,nn,w)

argument
WPA; Pascal value data
Nn;平均を取る回数
W;Optional (1 or 2)

Functions of the function
If w=1
Divide the data wpa of Pascal values into nn pieces. While using a humming window for each divided data, the A-weighted sound pressure level is determined by weighting from 10 Hz.$L_{10,A,n}$

$$L_{10,A,n} = 20 * log10(\frac{P_{10,A,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{20,A,n}$
$(P_{10,A,T})^2 = ((P_{10,A,1})^2 + (P_{10,A,2})^2 + \cdots + (P_{10,A,nn})^2)/nn$
It becomes, from,$P_{10,A,T}$

$$L_{10,A,T} = 20 * log_{10}(\frac{P_{10,A,T}}{0.00002})$$

and return this value.
The formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

It is a calculation close to that.

If w=2
Divide the data wpa of Pascal values into nn pieces. Using a Hamming window for each divided data, calculate spectrum(), cut out the components in the range of frequencies (10Hz~20kHz) handled by weighting from 10Hz, and obtain the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers.$P_{10,p,T}$

$$L_{10,P,T} = 20 * log_{10}(\frac{P_{10,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets

AVGLAeqSq

/***/

/* AVGLAeqSqHm (2022.7.17) */
AVGLAeqSqHm(wpa,nn,w)

argument
WPA; Pascal value data
Nn;平均を取る回数
W;Optional (1 or 2)

Functions of the function
If w=1
Divide the data wpa of Pascal values into nn pieces. While using a humming window for each divided data, the A-weighted sound pressure level is determined by weighting from 6.3 Hz.$L_{63,A,n}$

$$L_{63,A,n} = 20 * log10(\frac{P_{63,A,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{63,A,n}$

$(P_{63,A,T})^\wedge 2 = ((P_{63,A,1})^\wedge 2 + (P_{63,A,2})^\wedge 2 + \cdots + (P_{63,A,nn})^\wedge 2)/nn$

It becomes, from,$P_{63,A,T}$

$$L_{63,A,T} = 20 * log_{10}(\frac{P_{63,A,T}}{0.00002})$$

and return this value.

The formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} / P_0\right\}$$

It is a calculation close to that.

If w=2
Divide the data wpa of Pascal values into nn pieces. Using a Hamming window for each divided data, we calculate s pectrum() to extract the components in the range of frequencies (6.3Hz ~ 20kHz) handled by weighting from 6.3Hz, and obtain the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers.$P_{63,p,T}$

$$L_{63,P,T} = 20 * log_{10}(\frac{P_{63,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets
AVGLAeqSq

/***/

/* AVGLGeq7196SqHm (2022.7.16) */
AVGLGeq7196SqHm(wpa,nn,w)

argument
WPA; Pascal value data
Nn;平均を取る回数
W;Optional (1 or 2)

Functions of the function
w = 1 の場合
Divide the data wpa of Pascal values into nn pieces. While using a humming window for each divided data, the G-weighted sound pressure level is determined by weighting from 0.25 Hz$L_{25,G,n}$.

$$L_{25,G,n} = 20 * log10(\frac{P_{25,G,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{25,A,n}$
$(P_{25,G,T})\hat{}2 = ((P_{25,G,1})\hat{}2 + (P_{25,G,2})\hat{}2 + \cdots + (P_{25,G,nn})\hat{}2)/nn$
It becomes, from,$P_{25,G,T}$

$$L_{25,G,T} = 20 * log_{10}(\frac{P_{25,G,T}}{0.00002})$$

and return this value.
The following equation in the manual of the NL-62 of the company of Lion changed A to G

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

It is a calculation close to that.

If w=2
Divide the data wpa of Pascal values into nn pieces. Using a Hamming window for each divided data, we calculate s pectrum(), cuts out the components in the range of frequencies (0.25Hz~315Hz) handled by weighting from 0.25Hz, and finds the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers.$P_{63,p,T}$

$$L_{25,P,T} = 20 * log_{10}(\frac{P_{25,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets
AVGLGeqSq

/***/

/* AVGLGeqSqHm (2022.7.17) */
AVGLGeqSqHm(wpa,nn,h,w)

argument
WPA; Pascal value data
Nn;平均を取る回数
h;A number between 0 and 1 that determines the lower frequency limit of a bandpass filter with a center frequency of 1 Hz.
W;Optional (1 or 2)

Functions of the function
h;When the value of h is between the lower frequency of the band with a center frequency of 1 Hz and 0, the lower limit of this bandpass filter
The frequency is changed to h.

If w=1
Divide the data wpa of Pascal values into nn pieces. While using a humming window for each divided data, the G-weighted sound pressure level is determined by weighting from 1 Hz.$L_{1,G,n}$

$$L_{1,G,n} = 20 * log10(\frac{P_{1,G,n}}{0.00002})$$

Obtain the sound pressure that becomes.$P_{1,G,n}$
$(P_{1,G,T})\hat{}2 = ((P_{1,G,1})\hat{}2 + (P_{1,G,2})\hat{}2 + \cdots + (P_{1,G,nn})\hat{}2)/nn$
It becomes, from,$P_{1,G,T}$

$$L_{1,G,T} = 20 * log_{10}(\frac{P_{1,G,T}}{0.00002})$$

and return this value.
The following equation in the manual of the NL-62 of the company of Lion changed A to G

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} / P_0\right\}$$

It is a calculation close to that.

If w=2

Divide the data wpa of Pascal values into nn pieces. Using a Hamming window for each divided data, we calculate s pectrum() to extract the components in the range of frequencies (1Hz~80Hz) handled by weighting from 1Hz, and obtain the sum of the squares. Let be the square root of the additive mean of the obtained nn numbers. $P_{1,p,T}$

$$L_{1,P,T} = 20 * log_{10}(\frac{P_{1,P,T}}{0.00002})$$

The weight is calculated as 0.

Reference worksheets
AVGLGeqSq

/**/

/* AVGLAeq20HzHm (2022.7.14) */
AVGLAeq20HzHm(wpa,nn,h)

argument
WPA; Pascal value data
Nn;平均を取る回数
W;Optional (1 or 2)

Functions of the function
If w=1
Divide the data wpa of Pascal values into nn pieces. While using a humming window for each divided data, the A-weighted sound pressure level is determined by weighting from 20 Hz. $L_{20,A,n}$Returns $L_{20,A,n}$the additive mean of NN
The calculation method is different, but the formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N}P_A^2(i)\right)^{\frac{1}{2}}/P_0\right\}$$

It is close to the value of.

If w=2
Divide the data wpa of Pascal values into nn pieces. While using a Hamming window for each divided data, s pectrum() is calculated, the components in the range of frequencies (20Hz ~ 20kHz) handled by weighting from 20Hz are cut out, the weight is 0, the sound pressure level is obtained by nn, and the additive average is returned.

Reference worksheets
AVGLAeq

/***/

/* AVGLAeq10HzHm (2022.7.14) */
AVGLAeq10HzHm(wpa,nn,h)

argument
WPA; Pascal value data
Nn;平均を取る回数
W;Optional (1 or 2)

Functions of the function
If w=1
Divide the data wpa of Pascal values into nn pieces. While using a humming window for each divided data, the A-weighted sound pressure level is determined by weighting from 10 Hz. $L_{10,A,n}$Returns $L_{10,A,n}$the additive mean of NN

The calculation method is different, but the formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

It is close to the value of.

If w=2
Divide the data wpa of Pascal values into nn pieces. Using a Hamming window for each divided data, we calculate s pectrum(), cuts out the components in the range of frequencies (10Hz ~ 20kHz) handled by weighting from 10Hz, calculates the sound pressure level by nn with a weight of 0, and returns the additive average.

Reference worksheets
AVGLAeq

/***/

/* AVGLAeqHm (2022.7.14) */
AVGLAeqHm(wpa,nn,h)

argument
WPA; Pascal value data
Nn;平均を取る回数

W;Optional (1 or 2)

Functions of the function

If w=1

Divide the data wpa of Pascal values into nn pieces. While using a humming window for each divided data, the A-weighted sound pressure level is determined by weighting from 6.3 Hz$L_{63,A,n}$. Returns $L_{63,A,n}$the additive mean of NN

The calculation method is different, but the formula in the manual of the NL-62 of the company Lion,

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} / P_0\right\}$$

It is close to the value of.

If w=2

Divide the data wpa of Pascal values into nn pieces. While using a Hamming window for each divided data, spectrum() is calculated, the components in the range of frequencies (6.3Hz ~ 20kHz) handled by weighting from 6.3Hz are extracted, the weight is 0, the sound pressure level is obtained by nn, and the additive average is returned.

Reference worksheets

AVGLAeq

/***/

/* AVGLGeq7196Hm (2022.7.23) */

AVGLGeq7196Hm(wpa,nn,h)

argument

WPA; Pascal value data

Nn;平均を取る回数

W;Optional (1 or 2)

Functions of the function

If w=1

Divide the data wpa of Pascal values into nn pieces. While using a humming window for each divided data, the G-weighted sound pressure level is determined by weighting from 0.25 Hz$L_{25,G,n}$. Returns $L_{25,G,n}$the additive mean of NN

The calculation method is different, but the following formula in the manual of the NL-62 of the company of Lion changed A to G

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

It is close to the value of.

If w=2

Divide the data wpa of Pascal values into nn pieces. While using a Hamming window for each divided data, we calculate spectrum(), cut out the components in the range of frequencies (0.25Hz ~ 315Hz) handled by weighting from 0.25Hz, obtain the sound pressure level by nn with the weight as 0, and return the additive average.

Reference worksheets
AVGLGeq

/***/

/* AVGLGeqHm (2022.7.14) */
AVGLGeqHm(wpa,nn,h,w)

argument
WPA; Pascal value data
Nn; Number of times to take the average
h;A number between 0 and 1 that determines the lower frequency limit of a bandpass filter with a center frequency of 1 Hz.
W;Optional (1 or 2)

Functions of the function
h;When the value of h is between the lower frequency of the band with a center frequency of 1 Hz and 0, the lower limit of this bandpass filter
The frequency is changed to h.

If w=1

Divide the data wpa of Pascal values into nn pieces. Using a Hamming window for each of the divided data, the G-weighted sound pressure level is determined by weighting from 1 Hz, and$L_{1,G,n}$ an $L_{1,G,n}$additive average of n n is returned.

The following equation in the manual of the NL-62 of the company of Lion changed A to G

$$L_{Aeq} = 20log_{10}\left\{\left(\frac{1}{N}\sum_{i=1}^{N} P_A^2(i)\right)^{\frac{1}{2}} /P_0\right\}$$

It will be close to the value.

If w=2

Divide the data wpa of Pascal values into nn pieces. While using a Hamming window for each divided data, spectrum() is calculated, the components in the range of frequencies (1Hz ~ 80Hz) handled by weighting from 1Hz are extracted, the weight is 0, the sound pressure level is obtained by nn, and the additive average is returned.

Reference worksheets

AVGLGeq

/***/

/* Pascal to decibel(2022.5.1) */

PatodB(wpa)

argument

WPA; Pascal value data

Functions of the function

Convert Pascal value data to decibel values

Reference worksheets

JFE2Weight

/* decibel to Pascal(2025.2.12) */

dBtoPa(wdb)

argument

WDB;Decibel value data

Functions of the function

Convert decibel value data to Pascal values

Reference worksheets

JFE2Weight

/***/

/* AVGSpectrumRcShift (2022.7.21) */
AVGSpectrumRcS(wpa,cl,s,w)

argument
WPA; Pascal value data
Cl;length of data to be cut out
S;starting position of the cutout
Option (1,2,3,4)

Functions of the function
From WPA, s*k+1(k=0,1,2,3... The data of length cl is cut out, and the frequency spectrum is calculated using the cut data while using a rectangular window, and the additive average of the frequency spectrum values is returned.
W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.
W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets
AVGSpectrumS

/***/

/* AVGSpectrumHmShift (2022.7.21) */
AVGSpectrumHmS(wpa,cl,s,w)

argument
WPA; Pascal value data
Cl;length of data to be cut out
S;starting position of the cutout
Option (1,2,3,4)

Functions of the function
From WPA, s*k+1(k=0,1,2,3... The frequency spectrum is calculated using the Hamming window, and the additive average of the frequency spectrum values is returned.
W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.

W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets
AVGSpectrumS

/***/

/* AVGSpectrumHnShift (2022.7.23) */
AVGSpectrumHnS(wpa,cl,s,w)

argument
WPA; Pascal value data
Cl;length of data to be cut out
S;starting position of the cutout
Option (1,2,3,4)

Functions of the function
From WPA, s*k+1(k=0,1,2,3... The frequency spectrum is calculated using the Hanning window, and the additive average of the frequency spectrum values is returned.
W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.
W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets
AVGSpectrumS

/***/

/* AVGSpectrumFtShift (2022.7.23) */
AVGSpectrumFtS(wpa,cl,s,w)

argument
WPA; Pascal value data
Cl;length of data to be cut out
S;starting position of the cutout
Option (1,2,3,4)

Functions of the function

From WPA, s*k+1(k=0,1,2,3... Calculate the frequency spectrum of the cut data using the flat-top window, and return the additive average of the frequency spectral values of the cut data.
W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.
W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets
AVGSpectrumS

/***/

/* AVGSpectrumRc (2022.7.19) */
AVGSpectrumRc(wpa,nn,w)

argument
WPA; Pascal value data
The number of times the frequency spectrum is calculated
Option (1,2,3,4)

Functions of the function
From WPA, the length of the data corresponding to the number of calculations nn is extracted, and the frequency spectrum is calculated using the extracted data using a rectangular window, and the additive average of the frequency spectrum values is returned.
W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.
W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets
AVGSpectrum

/**/

/* AVGSpectrumHm (2022.7.20) */
AVGSpectrumHm(wpa,nn,w)

argument
WPA; Pascal value data

The number of times the frequency spectrum is calculated

Option (1,2,3,4)

Functions of the function

From WPA, the length of the data corresponding to the number of calculations nn is extracted, and the frequency spectrum is calculated using the extracted data using the Hamming window, and the additive average of the frequency spectrum values is returned.

W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.

W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.

W=3;The x-axis is a linear scale, and the value is a decibel value.

W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets

AVGSpectrum

/**/

/* AVGSpectrumHn (2022.7.23) */

AVGSpectrumHn(wpa,nn,w)

argument

WPA; Pascal value data

The number of times the frequency spectrum is calculated

Option (1,2,3,4)

Functions of the function

From WPA, the length of the data corresponding to the number of calculations NN is extracted, and the frequency spectrum is calculated using the Hanning window to calculate the frequency spectrum of the cut data, and the additive average of the frequency spectrum values is returned.

W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.

W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.

W=3;The x-axis is a linear scale, and the value is a decibel value.

W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets

AVGSpectrum

/**/

/* AVGSpectrumFlattop (2022.7.23) */
AVGSpectrumFt(wpa,nn,w)

argument
WPA; Pascal value data
The number of times the frequency spectrum is calculated
Option (1,2,3,4)

Functions of the function
From WPA, the length of the data corresponding to the number of calculations NN is extracted, and the frequency spectrum is calculated using the cut data while using a flat top window, and the additive average of the frequency spectrum values is returned.
W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.
W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets
AVGSpectrum

/***/

/* SeqSpectrumRcShift (2022.7.21) */
SeqSpectrumRcS(wpa,cl,s,w)

argument
WPA; Pascal value data
Cl;length of data to be cut out
S;starting position of the cutout
Option (1,2,3,4)

Functions of the function
From WPA, s*k+1(k=0,1,2,3... The data of the length cl is cut out, and the frequency spectrum is calculated using the cut data while using a rectangular window, and the sequence of them is returned.
W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.
W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets
Ty4SeqSpectrumS

/**/

/* SeqSpectrumHmShift (2022.7.21) */
SeqSpectrumHmS(wpa,cl,s,w)

argument
WPA; Pascal value data
Cl;length of data to be cut out
S;starting position of the cutout
Option (1,2,3,4)

Functions of the function
From WPA, s*k+1(k=0,1,2,3... The data of length cl is cut out, and the frequency spectrum is calculated using the cut data while using the Hamming window, and the sequence is returned.
W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.
W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets
Ty4SeqSpectrumS

/**/

/* SeqSpectrumHnShift (2022.7.23) */
SeqSpectrumHnS(wpa,cl,s,w)

argument
WPA; Pascal value data
Cl;length of data to be cut out
S;starting position of the cutout
Option (1,2,3,4)

Functions of the function
From WPA, s*k+1(k=0,1,2,3... The data of the length cl is cut out, and the frequency spectrum of the cut data is calculated using the Hanning window, and the sequence is returned.

W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.
W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets
Ty4SeqSpectrumS

/***/

/* SeqSpectrumFtShift (2022.7.23) */
SeqSpectrumFtS(wpa,cl,s,w)

argument
WPA; Pascal value data
Cl;length of data to be cut out
S;starting position of the cutout
Option (1,2,3,4)

Functions of the function
From WPA, s*k+1(k=0,1,2,3... The frequency spectrum is calculated using the flat-top window, and the frequency spectrum is calculated using the data to be cut out, and the data is returned in an arranged manner.
W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.
W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets
Ty4SeqSpectrumS

/**/

/* SeqSpectrumRc (2022.7.20) */
SeqSpectrumRc(wpa,nn,w)

argument
WPA; Pascal value data
nn;number of times to average
Option (1,2,3,4)

Functions of the function

From WPA, the length of the data corresponding to the number of calculations nn is extracted, and the frequency spectrum is calculated using the rectangular window, and the frequency spectrum is calculated using the extracted data, and the sequence is returned.

W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.
W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets

Ty4SeqSpectrum

/**/

/* SeqSpectrumHm (2022.7.20) */

SeqSpectrumHm(wpa,nn,w)

argument

WPA; Pascal value data

nn;number of times to average

Option (1,2,3,4)

Functions of the function

From WPA, the length of the data corresponding to the number of calculations nn is extracted, and the frequency spectrum is calculated using the cut data while using the Hamming window, and the sequence of them is returned.

W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.
W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets

Ty4SeqSpectrum

/**/

/* SeqSpectrumHn (2022.7.23) */

SeqSpectrumHn(wpa,nn,w)

argument
WPA; Pascal value data
nn;number of times to average
Option (1,2,3,4)

Functions of the function

From WPA, the length of the data corresponding to the number of calculations nn is extracted, and the frequency spectrum is calculated using the Hanning window to calculate the cut data, and the sequence is returned.

W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.
W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets
Ty4SeqSpectrum

/**/

/* SeqSpectrumFt (2022.7.23) */
SeqSpectrumFt(wpa,nn,w)

argument
WPA; Pascal value data
nn;number of times to average
Option (1,2,3,4)

Functions of the function

From WPA, the length of the data corresponding to the number of calculations nn is extracted, and the frequency spectrum is calculated using the cut data while using a flat top window, and the sequence is returned.

W = 1; The x-axis is a logarithmic scale, and the value is a decibel value.
W=2;The x-axis is a logarithmic scale, and the value is a Pascal value.
W=3;The x-axis is a linear scale, and the value is a decibel value.
W=4;The x-axis is a linear scale, and the value is a Pascal value.

Reference worksheets
Ty4SeqSpectrum

/***/

/* Change Pascal Value */
ChangePV(wpa,hz,pa)

argument
WPA; Pascal value data
Hz;Frequency to specify
pa; the pascal value to specify

Functions of the function
Returns the waveform of the WPA data when the frequency Hz component becomes PA Pascal.

Reference worksheets
NL1d3GCPV

/***/

/* Weight 1d3 G (2022.5.1)　(1Hz::80Hz) */
Weight1d3G(wsp,h,w)

argument
Wsp;Frequency Spectrum
h; A number that specifies the lower limit of the center frequency of 1 Hz (no change when h = 1)
Option (1,2,3)

Functions of the function
We will examine the weighting of the G-response (1 Hz to 80 Hz) with respect to the frequency spectrum.
W=1;Returns the result of the weighting displayed in Pascal values.
w=2;Returns the result of the weighting displayed in decibels.
w=3; returns a graph representing the weights.

Reference worksheets
Ty4WeightG

/***/

/* Weight 1d3 G IOS7196 (2022.5.10)　(0.25Hz::315Hz) */
Weight1d3G7196(wsp,w)

argument

Wsp;Frequency Spectrum

Option (1,2,3)

Functions of the function

We will examine how the weighting is done in the G characteristic (0.25 Hz to 315 Hz) with respect to the frequency spectrum.

W=1;Returns the result of the weighting displayed in Pascal values.

w=2;Returns the result of the weighting displayed in decibels.

w=3; returns a graph representing the weights.

Reference worksheets

Ty4WeightG

/**/

/* Weight 1d3 A 20Hz (2022.6.23) (20Hz::20000Hz) */

Weight1d3A20Hz(wsp,w)

argument

Wsp;Frequency Spectrum

Option (1,2,3)

Functions of the function

We will examine the weighting of the A-characteristics (20 Hz to 20 kHz) relative to the frequency spectrum.

W=1;Returns the result of the weighting displayed in Pascal values.

w=2;Returns the result of the weighting displayed in decibels.

w=3; returns a graph representing the weights.

Reference worksheets

Ty4WeightA

/**/

/* Weight 1d3 A 10Hz (2022.5.10) (10Hz::20000Hz) */

Weight1d3A10Hz(wsp,w)

argument

Wsp;Frequency Spectrum
Option (1,2,3)

Functions of the function
We will examine the weighting of the A-weighting (10 Hz to 20 kHz) with respect to the frequency spectrum.
W=1;Returns the result of the weighting displayed in Pascal values.
w=2;Returns the result of the weighting displayed in decibels.
w=3; returns a graph representing the weights.

Reference worksheets
Ty4WeightA

/***/

/* Weight 1d3 A (2022.5.10) IEC 1672:2014 (6.3Hz::20000Hz) */
Weight1d3A(wsp,w)

argument
Wsp;Frequency Spectrum
Option (1,2,3)

Functions of the function
We will examine the weighting of the A-weighting (6.3 Hz to 20 kHz) with respect to the frequency spectrum.
W=1;Returns the result of the weighting displayed in Pascal values.
w=2;Returns the result of the weighting displayed in decibels.
w=3; returns a graph representing the weights.

Reference worksheets
Ty4WeightA

/***/

/* Niose Level Vary 48kHz (2022.8.11)*/
NoiseLevelVary48k(wpa)
argument
Wpa: Pascal value data, recorded at a sampling frequency of 48 kHz.

Functions of the function
Every 0.1 seconds, 0.25 seconds of data is used to calculate the A-weighted (20 Hz to 20 kHz) sound pressure

level.

Reference worksheets

Ty4NLVary

/***/

/* Niose Level Vary 24kHz (2022.8.11)*/

NoiseLevelVary24k(wpa)

argument

Wpa: Pascal value data, recorded at a sampling frequency of 24 kHz.

Functions of the function

Every 0.1 seconds, 0.25 seconds of data is used to calculate the A-weighted (20 Hz to 20 kHz) sound pressure level.

Reference worksheets

Ty4NLVary

/***/

/* Niose Level Total (2022.5.2)*/

NoiseLevelTotal(ww)

argument

Ww;data representing the sound pressure level for each frequency band

Functions of the function

Returns the overall sound pressure level.

Reference worksheets

Ty4NLVary

/***/

/* Niose Level 1d3 A 20Hz (2022.6.23) (20Hz::20000Hz) */

NoiseLevel1d3A20Hz(wpat,w)

argument

Wpat: the data of the Pascal value multiplied by the window function

Option (1,2,3,4)

Functions of the function

Returns the sound pressure rev for each frequency band.

w=1;Returns a column of sound pressure levels for each frequency band, weighted by the A characteristic (20Hz::20kHz).

Returns a column of sound pressure levels for each frequency band before weighting by W=2;A characteristics (20Hz::20kHz).

Returns the value at w=3;w=1 and the value of the center frequency.

Returns the value at w=4;w=2 and the value of the center frequency.

Reference worksheets

Ty4NoiseLevel

/**/

/* Niose Level 1d3 A 10Hz (2022.5.4) (10Hz::20000Hz) */

NoiseLevel1d3A10Hz(wpat,w)

argument

Wpat: the data of the Pascal value multiplied by the window function

Option (1,2,3,4)

Functions of the function

Returns the sound pressure rev for each frequency band.

w=1;Returns a column of sound pressure levels for each frequency band, weighted by the A characteristic (10Hz::20kHz).

W=2;Returns a column of sound pressure levels for each frequency band before weighting with A characteristics (10Hz::20kHz).

Returns the value at w=3;w=1 and the value of the center frequency.

Returns the value at w=4;w=2 and the value of the center frequency.

Reference worksheets

Ty4NoiseLevel

/**/

/* Niose Level 1d3 A (2022.5.1)　IEC 1672:2014　(6.3Hz::20000Hz) */
NoiseLevel1d3A(wpat,w)

argument
Wpat: the data of the Pascal value multiplied by the window function
Option (1,2,3,4)

Functions of the function
Returns the sound pressure rev for each frequency band.
w=1;Returns a column of sound pressure levels for each frequency band, weighted by the A characteristic (6.3Hz::20kHz).
W=2;Returns a column of sound pressure levels for each frequency band before weighting by A characteristics (6.3Hz::20kHz).
Returns the value at w=3;w=1 and the value of the center frequency.
Returns the value at w=4;w=2 and the value of the center frequency.

Reference worksheets
Ty4NoiseLevel

/***/

/* Niose Level 1d3 G IOS7196 (2022.5.1)　(0.25Hz::315Hz) */
NoiseLevel1d3G7196(wpat,w)

argument
Wpat: the data of the Pascal value multiplied by the window function
Option (1,2,3,4)

Functions of the function
Returns the sound pressure rev for each frequency band.
w = 1 ; Returns a column of sound pressure levels for each frequency band, weighted by G (0.25Hz::315Hz).
Returns a column of sound pressure levels for each frequency band before weighting with W=2;G characteristics (0.25Hz::315Hz).
Returns the value at w=3;w=1 and the value of the center frequency.
Returns the value at w=4;w=2 and the value of the center frequency.

Reference worksheets
Ty4NoiseLevelG

/***/

/* Niose Level 1d3 G (2022.5.1)　(1Hz::80Hz) */
NoiseLevel1d3G(wpat,h,w)

argument
Wpat: the data of the Pascal value multiplied by the window function
h: A value that specifies the lower frequency of the band with a center frequency of 1 Hz. (Do not change when h=1.))
Option (1,2,3,4)

Functions of the function
Returns the sound pressure rev for each frequency band.
w = 1 ; Returns a column of sound pressure levels for each frequency band, weighted by the G characteristic (1Hz::80Hz).
Returns a column of sound pressure levels for each frequency band before weighting with W=2;G characteristics (1Hz::80Hz).
Returns the value at w=3;w=1 and the value of the center frequency.
Returns the value at w=4;w=2 and the value of the center frequency.

Reference worksheets
Ty4NoiseLevelG

/***/

/* Wavelet Exponential type Frequency Text(2019.03.13)*/
WltFrequencyText(ww,omg,dn,digit,step,disp)

Functions of the function
Displays the frequency.

/***/

/* Gabor Simple FFT Wavelets */
GaborSimpleFFTCnj(si,wp,r)

Functions of the function
This is a subroutine used by FWltgaborsimpleFFT().

/**/

/* Fine Wavelet Transformation by gabor simple FFT wavelet. (2015.12.01)*/
FWltgaborsimpleFFT(ww,wp,r,dn)

Functions of the function
Use the Gabor function to perform the Wavelet calculations.

/**/

/* Fine Wavelet Transformation by gabor simple FFT wavelet. Frequency Text. (2019.03.13)*/
GFWltgaborsimpleFFT(ww,wp,r,dn,digit,step,disp)

Functions of the function
Display the frequency for the result of the wavelet analysis.