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PSYCHOACOUSTICS ANNOYANCE ANALYSIS FOR TWO WAY RADIO UNDER WIND NOISE

Mohd Khairul Rabani Hashim[1, 2], Abdullah Aziz Saad[1] and Zaidi Mohd Ripin[1]
[1]School of Mechanical Engineering, Universiti Sains Malaysia, Engineering Campus, Nibong Tebal, Pulau Pinang, Malaysia
[2]School of Bioprocess Engineering, Universiti Malaysia Perlis Kompleks Pusat Pengajian Jejawi, Arau, Perlis, Malaysia
E-Mail: mohdkhairulrabani@gmail.com

ABSTRACT

Noise generated from wind flow over the two-way radio can decrease communication effectiveness. Psychoacoustics parameters of loudness and sharpness are used to measure the effect of wind noise on the sound quality at wind speed of 2, 4, 6, 8 and 10 m/s. This was conducted through experimental work using anechoic box and wind tunnel setup. Loudness and sharpness results are used to measure psychoacoustics annoyance. The annoyance level decreases as the wind speed increase.

Keywords: psychoacoustics, annoyance, sharpness, loudness, two-way radio.

INTRODUCTION

Two way radio is widely used for verbal communication in work site which is usually in the open environment. Wind noise is known to affect the quality of the speech transmitted over the radio. However there are limited available literatures which discuss this problem. In this work wind noise effect on the sound quality of the transmitted signal is analyzed using psychoacustics parameters which are sharpness, loudness and annoyance.

Sharpness is a parameter that measure of the high frequency content of sound [1]. Sharpness is an index used to describe the proportional to spectral center of gravity. The unit of sharpness is acum. The sharpness of 60dB bandwidth noise is 1 acum, for the noise whose central frequency is 1kHz and bandwidth is 150Hz and a level at 60 dB [2]. Furthermore, sharpness also corresponds to the comparison of the amount of high frequency energy to the total energy [3].

Loudness is one characteristic of sound in the category of psychoacoustic which can indicate the subjective feeling of noise to human ear. The unit of loudness is sone and defining 1 sone is that a 1kHz pure acoustic signal of 40dB [2]. Zwicker loudness is usually adopted as the estimating parameter. It is based on the use of the 25 third octave bands between 20Hz and 12500Hz. The technique also weights the different third octave bands depending on their frequency and level for instance interpolating between the standard A, B and C networks as appropriate. Loudness is amplitude fluctuation measured below 20 per second. When the amplitude fluctuations are measured above 20 per second, the parameter to describe the signal is roughness [4].

Zwicker and Fastl [3] described a formula developed by Widmann [4] for the calculation of Psychoacoustics Annoyance (PA), which includes the parameters of loudness, sharpness, fluctuation strength and roughness

$$PA = N_5(1 + \sqrt{w^2{}_S + w^2{}_{FS}} \quad (1)$$

$$w_s = \left(\frac{S}{acum} - 1.75\right).0.25.\log\left(\frac{N_5}{sone} + 10\right) \quad (2)$$

For S > 1.75 acum

$$W_{FR} = \frac{2.18}{(N_5/sone)^{0.4}}\left(0.4.\frac{F}{vacil} + 0.6.\frac{R}{asper}\right) \quad (3)$$

acum), F is the fluctuation strength (vacil), and R is the roughness (asper).

Zwicker and Fastl [5] also described a formula for calculation of sensory pleasantness developed by Aures . In this formula, sensory pleasantness was calculated from the parameters of fluctuation strength, roughness, tonality and sharpness.

A major difference between annoyance and pleasantness is that loudness has a greater influence on annoyance than on pleasantness. Therefore, characterization of annoyance should be used rather than a characterization of pleasantness. According to Aures [6], the tonality increases the pleasantness, while Kryter and Pearson [7] state that tonal sounds are more annoying than noises under the same circumstances. Tonality was not included in this formula for PA which presupposes no pure tones in the sound, and it was assumed small because of the spectral width of the impulsive closing sounds.

Because of the short duration of the closing sounds, a modification of the formula for PA calculation developed by Widmann was carried out in the present study. Since the closing sounds were of extremely short duration, the percentile loudness N_5 was replaced by a mean of peak values of loudness, including temporal effects. Calculations of fluctuation strength and roughness were omitted in this modified formula. This emission was

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performed because the modulation frequencies which elicit the largest roughness are about 70 Hz. These frequencies correspond to a time period of about 14 ms, which is longer than the duration of a common closing sound. The time periods of fluctuation strength are even longer, corresponding to time periods of about 33 ms and more. The third modification to the formula of Widmann is that sharpness was calculated using Aures' method [6], thus improving level independence. As for loudness, a mean of peak values (corresponding to the loudness values) was used.

The modified Widmann formula thus became:

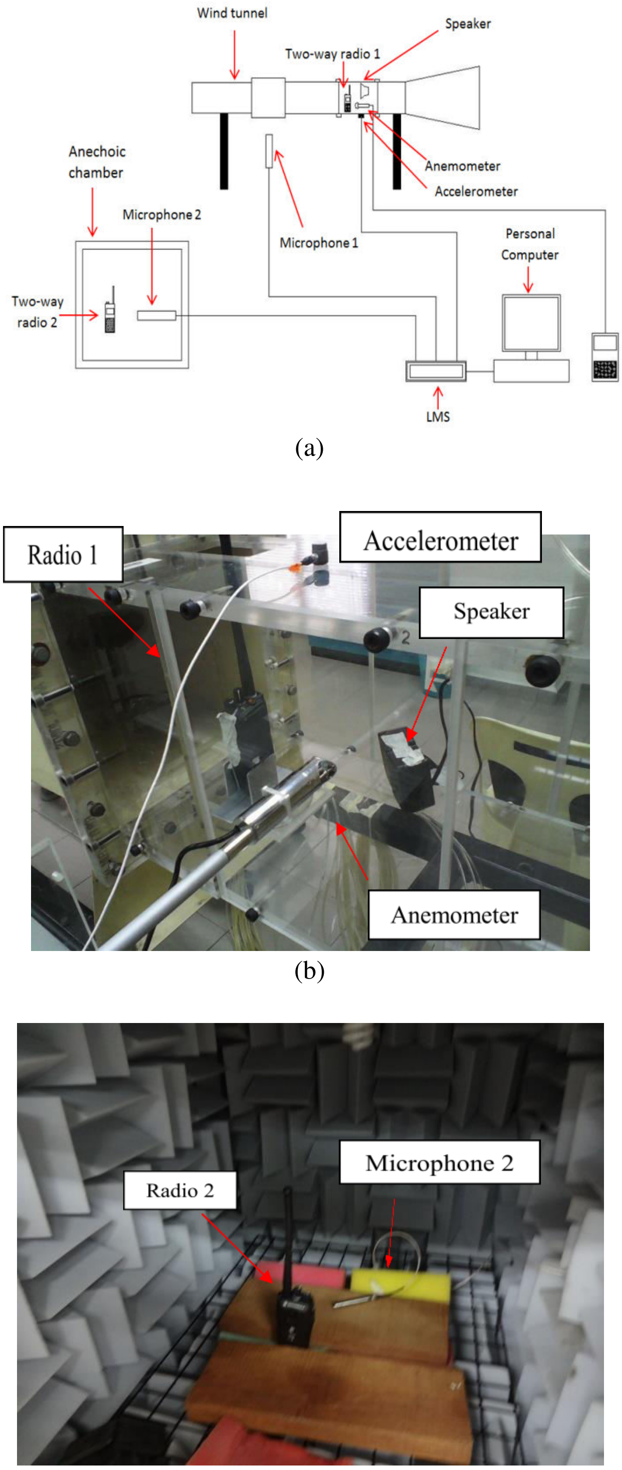
$$PA = \frac{N}{sone}\left(1 + \left(\frac{S}{acum} - 1.75\right).0.25.\log\left(\frac{N}{sone} + 10\right)\right) \quad (4)$$

The objective of this work is to determine the effect of wind noise on the quality of the sound signal transmitted over the two way radio.

METHODOLOGY

A pair of commercially available two way radios was used as the object of study. The transmitter was located inside the working space of an open-ended wind tunnel. The speed of the wind was controlled by the speed of the fan motor and the wind speed was measured using the hot wire anemometer. The transmitter was positioned at an angle of attack 90° to the free stream direction of the wind flow. The transmitted sound was captured by the receiver and the sound signal generated by the speaker was measured by a microphone with sensitivity 51.9mV/Pa or -25.7dB re 1 V/Pa. Both the receiver and microphone with sensitivity 47.3mV/Pa or -26.5dB re 1 V/Pa were located inside an anechoic box in order to prevent the outside noise from being measured. Measurement of the ambient noise was also conducted by mounting one microphone outside the wind tunnel. In order to identify any structural or mechanical noise due to the vibration of the machines (motor and fan blades) and the wind tunnel, an accelerometer with sensitivity 101.5 mV/g was mounted on the frame supporting the wind tunnel near the work space of the wind tunnel. All the signals from the two microphones and accelerometer were fed into the LMS Test Lab data acquisition system (LMS-8 Channel Test Lab System) and the captured signals were processed offline using the Sound Quality Analysis software by LMS Test Lab 10. In order to include the effect of speech intelligibility a speaker was located within the wind tunnel but at 200 mm away from the radio in order to provide the input speech to the two way radio. Three wind speed conditions were investigated namely 0, 2 and 6 m/s wind speed.

The experimental setup is shown in Figure-1 below. In this figure it can be seen the location of the radio inside the wind tunnel together with the speaker for the speech generation.



(c)

Figure-1. (a) Schematic of the setup and (b) Close up photo of the inside the wind tunnel and (c) Close up photo of the anechoic chamber.

Psychoacoustics annoyance level of the speech testing results was measured by using designed measurement system in LabView software. Figure-2 shows the block diagram of psychoacoustics annoyance measurement system. Input sound source for the system

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was a received signal from the speech testing result. Loudness and sharpness level of the signal was calculated and transferred into formula block. Inside of formula block, psychoacoustics annoyance was calculated based on the 3rd modification PA formula. Output of the system was recorded and analyzed.

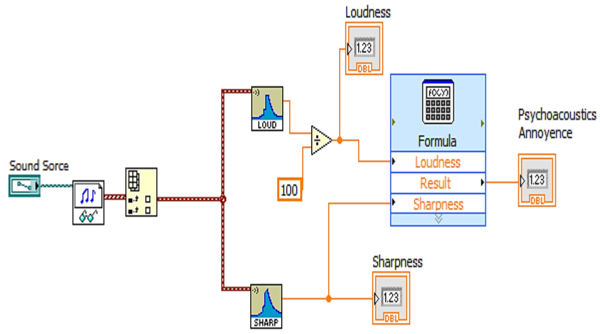

Figure-2. Block diagram of PA measurement system.

RESULT AND DISCUSSIONS

A. Effect of wind speed

The data obtained are first subjected to Fast Fourier Transform (FFT) analysis in order to identify the presence of dominant frequencies. Figure 3 shows the spectrum of the SPL for three different wind speeds of 0, 2 and 6 m/s. From the figure, for condition without wind noise, the spectrum shows the relatively high SPL component of frequencies below 1000Hz. As the speed increases to 2 m/s, the amplitude for the frequency components between 1000Hz-4000Hz increase significantly. Amplitude of frequency increase double when the wind speed of 6 m/s. The possible reason is the increase of the vortex strength due to the increase of the velocity of the wind [8]. In general, all the frequency components above 3000Hz are not detectable due to cut-off frequency of the sampling at 3000Hz. Based on discussion, amplitude of frequency components increase as the wind speed increase especially at below 1000 Hz.

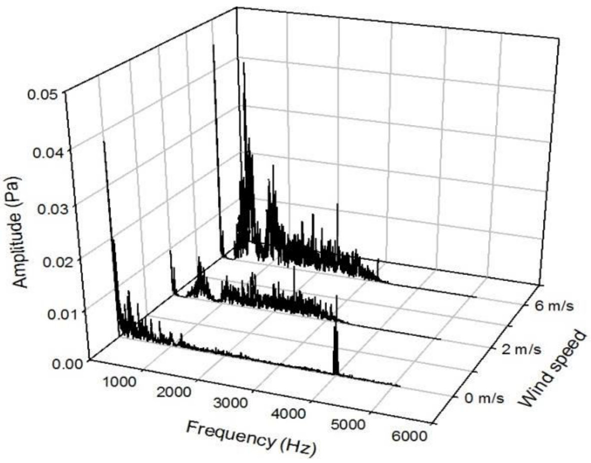

Figure-3. FFT of the wind noise for different wind speed.

B. Sharpness

Figure-4 shows the sharpness result for various wind speeds. Based on the figure, the sharpness level fluctuates over the measurement time. The highest peak is remarked at 1.44 acum during speech period at no wind speed. The highest peaks for every wind speed are decreasing as the wind speed increase. The highest amplitude for wind speed of 10 m/s is 1.37 acum. Besides, the amplitude ranges for every wind speed also narrow down as the wind speed is increase as shown in Table-1. Distance between the peak and lower sharpness become smaller. Table-1 shows the summarized result from Figure-4.

Sharpness level depends highly on high frequency components. The sharpness level can be lowered down by adding low frequency components to the signal [9]. Based on FFT results in Figure, composition of high and low frequency components are affected by the development of frequency component between 580Hz to 800Hz. The frequency composition is shifted to high frequency components as the wind speed is increasing. As the results, the sharpness becomes higher as the wind speed increases which can be clearly seen during the silent period.

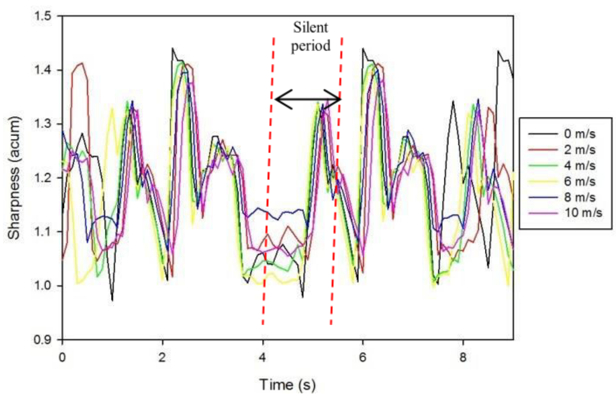

Figure-4. The graph of sharpness versus time for various wind speed.

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Table-1. The table of sharpness properties at various wind speed.

Wind speed (m/s)	**Sharpness level** (acum)		
	Lowest	**Peak**	**Range**
0	0.97	1.44	0.47
2	1.00	1.41	0.41
4	1.02	1.41	0.39
6	1.00	1.38	0.38
8	1.18	1.38	0.2
10	1.16	1.36	0.2

C. Loudness

Figure-5 shows the loudness effect of received signal under different wind speed. Trend of loudness level is increases as the wind speeds increase. During the silent period, loudness level is below than 20 sone without wind speed and the level increases to 50 sone when the wind starts to flow at 2 m/s. The highest loudness level at silent period is above 80 sone with the wind speed 10 m/s. The loudness level has no different during speech period. Basically, the loudness level depends highly on SPL and bandwidth of a sound signal [10].

Fluctuated level of loudness is nice to be listened compared to small changing of the loudness level [11]. From Figure-5, fluctuated range of loudness level smaller as the wind speed increase. This result proves that the received signal at lower wind speed is nice to be listened. The radio may dangerous for long-term exposition due to limitation of safety is 32 sone. The radio should be used at lower volume rate in order to prevent from hearing damage.

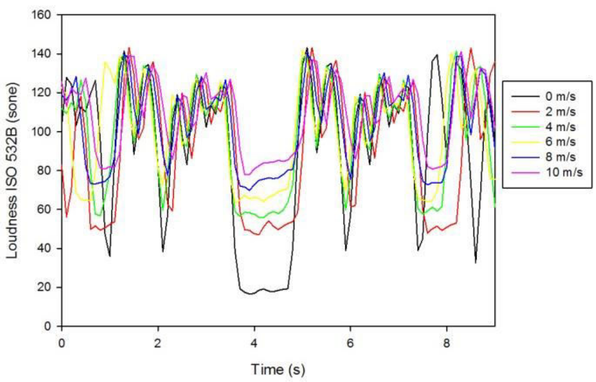

Figure-5. The graph of loudness ISO 532B versus time for various wind speed

D. Psychoacoustics annoyance

Figure-6 shows the results of psychoacoustics annoyance for various wind speeds. Generally, psychoacoustic annoyance level increases as the wind speeds increase. Annoyance level is 0.4221 without wind speed. The annoyance level increases continuously as the wind speeds increase until it reaches the highest level 0.4743 at wind speed of 10 m/s. From the graph, the stiffness of annoyance level becomes stiffer when the wind speed rises from 6 m/s to 10 m/s. The annoyance level is predicted to become worse as the wind speeds increase. Table-2 shows the summary of psychoacoustics annoyance level for speech under various wind speeds.

Annoyance level for speech signal under wind noise found in this study is lower compared to other studies. According to study by Arne in 2008 [12], annoyance level of automobile power window is 0.98, which is higher compared to the worst case of speech signal under wind speed 10m/s. The situation happen due to sharpness level of automobile window is higher compared to speech under wind noise. Psychoacoustics annoyance level is important product design. For instance, a dentist’s drill is very annoyance not because of its loudness but its sharpness [13]. Based on the annoyance level, a good design of two ways radio’s system can be designed.

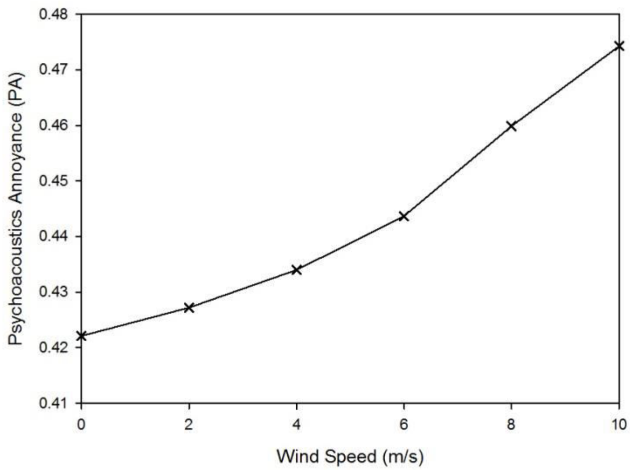

Figure-6. The graph of psychoacoustics annoyance for various wind speed.

Table-2. Table of psychoacoustic annoyance at various wind speed.

Wind speed (m/s)	**Psychoacoustic annoyance** (PA)
0	0.4221
2	0.4272
4	0.4340
6	0.4437
8	0.4599
10	0.4743

CONCLUSIONS

The quality of the wind noise of the two-way radio showed increased level of loudness and decrease level of sharpness with the increase in speed. Psychoacoustics annoyance analysis showed that higher wind speed results the highest value of PA.

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