Measurement of Airborne Noise Emitted by Low Noise Small Fans Using the Cross Spectrum method

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Abstract

It is practically needed to determine the sound power level of a low noise sound source, such as a small fan used in a notebook PC. However, by use of ordinary WS2 type microphones, it is difficult to perform accurate measurement, since the self-noise of the microphone is often louder than the noise emitted by the sound source. The cross-spectrum method is employed for the noise reduction in this measurement. It is shown that sound power levels of low noise fans can be determined practically in sufficient accuracy using ordinary WS2 type microphones by the cross spectrum method.

1. Introduction

Sound power level of a fan is usually determined by the pressure method specified in ISO3744, 3745[1] or ISO10302[2]. By this method, sound pressures are measured on a semi-spherical surface with a radius of 1m or more around the sound source in a semi-anechoic room. However, it is difficult to perform exact measurement by use of an ordinary WS2 type microphone, since the self-noise of the microphone is often louder than the sound pressure emitted by the sound source. In this paper, the cross spectrum method is employed for the noise reduction in the measurement for a low noise fan. In addition to the microphone measuring the airborne noise of a fan, some reference microphones are placed close to the sound source[3].

The pressure values correlated with the reference microphones’ outputs are computed from the output of the measuring microphone.

2. Cross spectrum method

Fig.1 shows the block diagram of the measurement system. The output signal of the measuring microphone and the i-th reference microphone, $m(\omega)$ and $r_i(\omega)$ are expressed as follows respectively

$$m(\omega)=m_s(\omega)+m_n(\omega)$$
$$r_i(\omega)=r_{si}(\omega)+r_{ni}(\omega)$$

Where $\omega$ is the angular frequency, $m_s$ and $r_{si}$ are the component correlated to the sound source. $m_n$ and $r_{ni}$ are the noise component. The cross power spectrum vector $\Phi(\omega)$ and the cross power spectrum matrix $R(\omega)$ are measured by a FFT analyzer. These cross spectrum values are as follows.

$$\Phi_i(\omega)=\langle r_i(\omega) \ast m(\omega) \rangle$$
$$R_{ij}(\omega)=\langle r_i(\omega) \ast r_j(\omega) \rangle$$

Where $\langle \rangle$ denotes a time averaging and suffix “*” denotes the complex conjugate value. Since $m_s$ and $r_{si}$ has no correlation with $m_n$ and $r_{ni}$, $\Phi$ and $R$ can be expressed as follows.

$$\Phi=\Phi_s+\Phi_n$$
$$R=R_s+R_n$$

Figure.1 Block diagram of noise reduction system using cross-spectrum method.
Where $\Phi_s$ and $R_s$ are the cross spectrum matrix concerned with the sound source. $\Phi_n$ and $R_n$ are the cross spectrum matrix concerned with the noise and can be determined by the measurement when the sound source is cut off. Then the target value $|m_s(\omega)|$ is obtained as follows

\[ |m_s(\omega)|^2 = \Phi_s^* R_s^{-1} \Phi_s \]

(7)

3. Measurement conditions

Sound pressures emitted by a low noise small fan mounted on a plenum box[2] were measured by two methods. One method is using WS2 type microphones with the noise reduction by the cross-spectrum method. The other is the direct measuring using TYPE 4179 microphones of high sensitivity. Fig.2 shows the background noise using ordinary WS2 microphone Type 4190 and high sensitivity microphone Type 4179. It seems that exact measurement is impossible using 4190 microphones.

The measurement conditions are as follows.

- Measuring microphone: type 4190 & Type 4179 in the place of 1m in front of the sound source.
- Reference microphones: two microphones of type 4165, one is in the place of 10cm above the sound source and the other is 20cm in front of the source.
- Sound source: a low noise small fan mounted on a quarter size plenum (30cm*30cm*25cm)
- FFT analyzer: frequency range 16kHz and 1.6kHz, sampling point 2048, Hanning window, averaging time 50 s

4. Measurement result

Fig.3 shows the measured values of one-third octave band level of the airborne noise emitted by a small fan. Cross spectrum method using 2 reference microphones and 1 reference microphone are tested. Both values using 2 and 1 reference microphones are similar to the values measured directly by Type 4179 microphone.

5. Conclusion

By use of ordinary WS2 microphones with cross spectrum method for noise reduction, it is able to measure in sufficient accuracy sound power levels of low noise fans

6. References

[1] ISO3744, ISO3745: “Determination of sound power levels of noise sources using sound pressure”