

A BASIC STUDY OF AN ENVELOPE INTENSITY

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1. INTRODUCTION

The sound intensity method is used quite often in the field of noise control. Since the sound intensity method mostly used is the time averaged sound intensity, it is basically applicable only to a stationary noise. However, there are many cases in which it is needed to evaluate a transient noise. If the instantaneous intensity is used, it changes its sign (if the dc component is removed) too quickly and, therefore, it is not suitable in investigating the direction of the sound propagation. In this report, we introduce an envelope intensity and compare it with the instantaneous intensity. Also some application examples of this method is shown. A board is used as a sound reflector in an anechoic room. A burst sound is generated by a loudspeaker and the direct sound and the reflected sound by the board are analyzed by the envelope intensity. The second example is an analysis of a pulsive sound generated by hitting the reflecting board by an impact hammer used for the modal analysis.

2. DEFINITION OF THE ENVELOPE INTENSITY

The instantaneous sound intensity at a point in the space in the direction of the observation is given by

$$i(t) = p(t)v(t) \quad (1)$$

where $i(t)$ is the instantaneous intensity, $p(t)$ is the pressure, and $v(t)$ is the particle velocity. In case of a sinusoidal signal, such as

$$p(t) = P \cos(\omega t) \tag{2}$$

and $v(t) = V \cos(\omega t + q) \tag{3}$

where P and V are the pressure and velocity amplitudes of $p(t)$ and $v(t)$, respectively, and q is the phase difference between the pressure and velocity. Then the instantaneous intensity is given by

$$i(t) = PV[\cos(q) + \cos(2\omega t - q)]/2 \tag{4}$$

The frequency of the alternative component of the instantaneous frequency is twice of the original frequency. This property of the instantaneous intensity makes the observation of the direction of the energy flow difficult.

The time averaged sound intensity is given by

$$I_a = (1/T) \int_{-T/2}^{T/2} i(t) dt \quad (T \rightarrow \text{limit}) \tag{5}$$

When this is applied to the sinusoidal wave given by Eqs.(2) and (3), the averaged sound intensity becomes

$$I_a = PV \cos(q) / 2 \tag{6}$$

which is independent of time. If this method is forcefully applied to a transient sound, several problems arise. For example, if the averaging time is too long, the time varying nature is lost. Or, if a finite averaging time is used, the result is dependent on the length of the time window.

The envelope intensity, which has a property between the instantaneous intensity and the time averaged intensity, is defined as follows:

$$I_e(t) = \text{Re}[p_a(t)v_a^*(t)] \tag{7}$$

where $p_a(t)$ and $v_a(t)$ are the analytic functions of $p(t)$ and $v(t)$, respectively, and $\text{Re}[\]$ and \ast indicate the real part and the complex conjugate, respectively. For example, $p_a(t)$ is given by

$$p_a(t) = [p(t) - j \text{ph}(t)] / \sqrt{2} \tag{8}$$

where $\text{ph}(t)$ is a Hilbert transform of $p(t)$. In case of the sinusoidal wave, $p_a(t)$ and $v_a(t)$ are given by

$$p_a(t) = P \exp(j\omega t) / \sqrt{2} \tag{9}$$

$$\text{and } v_a(t) = V \exp(j\omega t - q) / \sqrt{2} \quad (10)$$

respectively. The envelope intensity is then given by

$$I_e(t) = P V \cos(q) / 2 \quad (11)$$

which is equal to the time averaged intensity in this special case.

3. APPLICATION EXAMPLES

The first example of the envelope intensity is for a burst sound generated by a loudspeaker in an anechoic room. The test setup is shown in Fig.1 The direct sound and the reflected sound by the particle board (900x900x20 in mm) are received by the two microphones. A method to obtain the particle velocity is the same as the conventional two microphone intensity probe technique. Fig.2 shows the result. The top, middle, and the bottom figures are the pressure, instantaneous intensity, and the envelope intensity, respectively. The pressure signal does not have directional information at all. The instantaneous intensity shows the direction of the wave packet propagation. However, it varies too fast making the observation rather complex. The envelope intensity, on the other hand, has a slowly varying nature as well as the directional property.

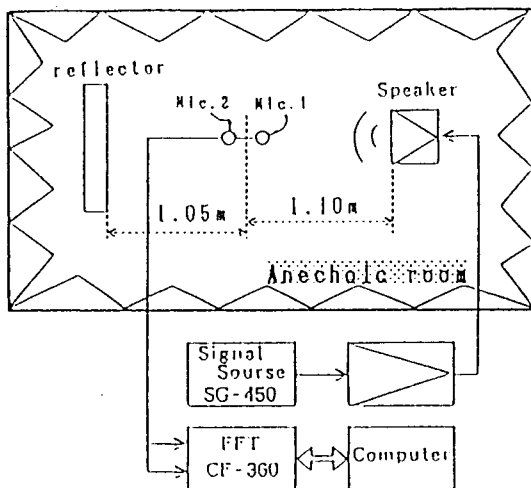


Fig.1 The experimental setup in an anechoic room.

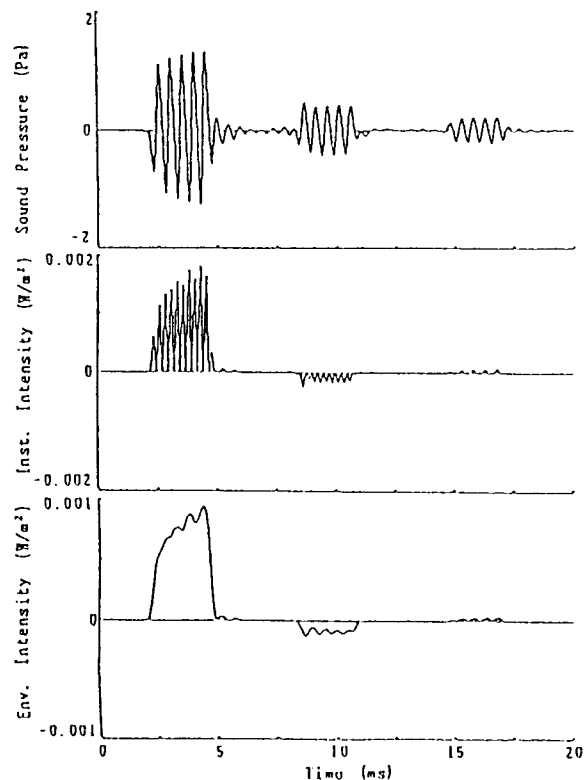


Fig.2 2kHz sinusoidal wave (5-wave burst).

Another example is shown in Fig.3. The same sound board as the first example is hit by an impact hammer at the point shown in Fig.3. A transient sound generated by the impact is measured in x and y directions at the measurement point. The top and bottom figures in Fig.3 show the continuous direction and the linear amplitude changes of the envelope and instantaneous intensities. The top figure clearly shows that the largest sound energy flow is from the impact point. The instantaneous intensity shows the direction of the impact but it varies too fast making the phenomenon look very complex.

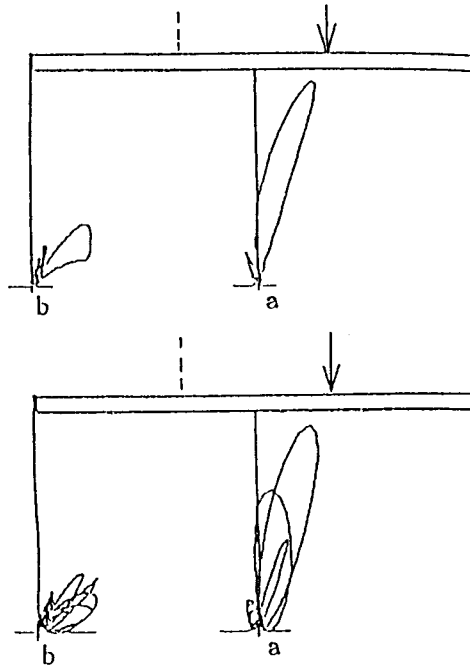


Fig.3 Envelope (top) and instantaneous intensities (bottom) of a board impact sound.

4. CONCLUSION

The envelope intensity was proposed as a method to analyse transient sounds. A basic study showed that the envelope intensity gives the slowly varying intensity magnitude and the direction of the wave packet, making the observation of the phenomenon easier than applying the instantaneous intensity. A usefulness of this method should be checked by applying it to various kinds of transient sound in real situations.

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