P - 11

THE PATTERNS OF THE SOUND INTENSITY DISTRIBUTION OF MIDRANGE LOUDSPEAKER

Septiana Nur Laely[1] and Agus Purwanto[2]
Vibration and Wave Laboratory, Physics Departement, Faculty of Mathematics and Science
Yogyakarta State University
CP: 08985110992[1], septhy_aina@yahoo.com

Abstract

This study aimed to determine the pattern of intensity vector distribution of the midrange loudspeaker at frequency 3000 Hz and 6000 Hz. The 3000 Hz was selected because human ear was very sensitive to this frequency, whereas the frequency 6000 Hz was selected as an output limit of the midrange loudspeaker. The data were collected by using two condenser microphone that was connected by using a Spectra Plus 5.0 program to the computer. The data (voice) were taken at a distance of 1 meter from the center of the loudspeaker. The distance between the sample points was 10° for one position and there were 36 points for each frequency. At each sample point on a position, a second condenser microphones rotated by 36 points around the first condenser microphone. The second condenser microphones rotation interval was 10. At frequency 3000 Hz, the pattern of sound intensity vector distribution tended to spread over the front and the left side of loudspeaker. While at frequency 6000 Hz, the pattern of sound intensity vector distribution focused to the front of loudspeaker.

Key words: frequency, the pattern of sound intensity distribution, midrange loudspeaker

INTRODUCTION

We hear sound coming from various sources. One source of the sound is the loudspeaker. There are several types of loudspeaker based on the sound produced. They are subwoofer, woofer, midrange, tweeter, full range, and horn (adapted from *http://en.wikipedia.org/wiki/Loudspeaker*).

The sound produced by the loudspeaker has certain patterns in its distribution. This is related to the frequency issued by the loudspeaker. If the loudspeaker sounds at low frequencies, the distribution pattern is in the form of an omnidirectional (evenly distributed at all points). However, if the loudspeaker sounds at high frequencies, the distribution pattern will be more focused. Directivity pattern needs to be known to determine the pattern of distribution of sound pressure. Through the directivity pattern, it can be seen the direction of propagation (focus) the spread of the sound. The intensity of the sound associated with the power and sound pressure generated by the sound source. However, the intensity of the sound is not the same physical quantity as sound pressure. Sound intensity is a vector quantity, while the sound pressure is a scalar quantity (do not have direction).

A. Summary of Problems

The summary of problem of this study is:

- The pattern of intensity vector distribution of the midrange loudspeaker at frequency 3000 Hz and 6000 Hz.

B. Research Objectives

The purpose of this study is:

- Determining the intensity distribution pattern of midrange loudspeaker at a frequency of 3000 Hz and 6000 Hz.

C. Benefits of the research

1. Practical benefits

   This study to determine the distribution patterns of sound intensity of the midrange loudspeaker could be used to provide recommendations to place loudspeaker appropriately.

2. The theoritical benefits

   The results can be used as reference for further research and development of science and technology.

THEORY

Directivity is a quantitative measure of the characteristic pattern of spread directions of a sound source. Loudspeaker (sound source) can be modeled by a piston with radius a mounted on a hard flat wall. Sound source surface is radially vibrating with a speed $U_0 e^{j\omega t}$. The pressure at any point of the field can be obtained by dividing the surface of the piston into smaller parts, each part acts as a simple source with power $dQ = U_0\, dx$. The sound pressure p (r, θ, t) emitted by the sound source (baffled piston) in the far-field (Kinsler et. all. 2000:182) is

$$p(r,\theta,t) = \frac{j}{2}\,\rho_o c\, U_o \frac{a}{r} ka \left[\frac{2J_1(ka\sin\theta)}{ka\sin\theta}\right] e^{j(\omega t - kr)} \qquad (1)$$

From the above equation is obtained magnitude of the directional factor H (θ) in the far-field is given by

$$H(\theta) = \left|\frac{2J_1(v)}{v}\right| ;\, v = ka\sin\theta \qquad (2)$$

where $J_1(v)$ is the Bessel function of the first order (Kinsler et. all. 2000:182).

Sound Intensity

Sound intensity vector I (t) is defined as the product of the sound pressure p (t) and particle velocity vector $\vec{u}$ (t) (Fahy, 1995:71):

$$\vec{I} = p.\vec{u} \qquad (3)$$

Sound pressure was measured in a circular field of radius r = 1 m parallel to the loudspeaker. In polar coordinates, the solution of the Helmholtz equation produces pressure which is inversely proportional to r (Kinsler et. all. 2000:127), so the pressure at each point is defined as

$$p(r,t) = \frac{A}{r}\cos(\omega t - kr + \emptyset) \qquad (4)$$

Calculation of $\vec{u}$ was approached using the pressure gradient which was approximated by sound pressure difference received by the microphone at a distance Δr, as follows:

$$\vec{\boldsymbol{u}} = -\frac{1}{\rho}\int\left(\frac{p_2 - p_1}{\Delta r}\right)\hat{r}\,dt \qquad (5)$$

Then the magnitude of sound intensity can be obtained at the point of measurement

$$\vec{\boldsymbol{I}} = -\frac{p_1+p_2}{2\rho\Delta r}\int(p_2-p_1)\,\hat{r}dt \qquad (6)$$

where Δr was the distance between the two microphones.

RESEARCH METHOD

A. Time and Place of Research

This study was conducted from January to July 2013, in the Laboratory of Vibration and Waves, Faculty of Math and Science, Yogyakarta State University.

B. Tools and Analysis Program

1. Equipment used:
    a. 1 midrange loudspeaker
    b. 2 condenser microphones
    c. 1 stative (poles)
    d. Circular arc 360^{o}
    e. Pre-amplifier, RE.031
    f. Amplifier, Uchida Model TA-2ms
    g. Audio Generator, TRIO AG-202A
    h. Connecting cable
    i. Laptop

2. Analysis programs used:
    a. Spectra Plus 5.0
    b. MatLab R2010a

3. Research Variables
    a. Independent variables: frequency of loudspeaker (3000 Hz and 6000 Hz).
    b. Dependent variables: the loudspeaker intensity pattern captured by the condenser microphone.
    c. Control variables: the distance between the loudspeaker and the condenser microphone, the distance between two condenser microphones, types of loudspeaker and condenser microphone.

C. Work Steps

1. Preparation
    Audio generator was connected to an amplifier and then to the loudspeaker. The 1st and 2nd microphone captured the sound produced by the loudspeaker then amplified by a pre-amplifier. The resulting amplifier output were displayed by Spectra Plus 5.0® program on the laptop.
2. Data Collection
    a. Adjust the handle of both microphone in front of the loudspeaker (the first sample point was 0°).
    b. Both of condenser microphone were arranged parallel to the direction of the sound. The first condenser microphone was stationary and the second was behind it (0° of two microphones).
    c. Record output that captured by two mirophones using Spectra Plus 5.0 program in a .wav file.

   d. Rotate the second condenser microphone as far as 10° from 0° to 360°.
   e. Record the output for other sample points (surrounding loudspeaker through 360°).

3. Data Analysis Techniques
   a. Take note of the output captured by a second condenser microphone (amplitude).
   b. Calculate the value of the pressure difference *p* between the two condenser microphones at each sample point for each frequency.
   c. Calculate the value of the particle velocity *u* at each sample point for each frequency.
   d. Calculate the value of intensity *I* at each sample point for each frequency.
   e. Calculate the value of the resultant of intensity at each sample point for each frequency.
   f. Draw vector of sound intensity at a distance of 1 m from the center of the loudspeaker using *CorelDraw* program.

RESULT AND DISCUSSION

Midrange Loudspeaker Sound Intensity Distribution

Intensity distribution of midrange loudspeaker at a frequency of 3000 Hz and 6000 Hz using two condenser microphones can be seen in the following figures:

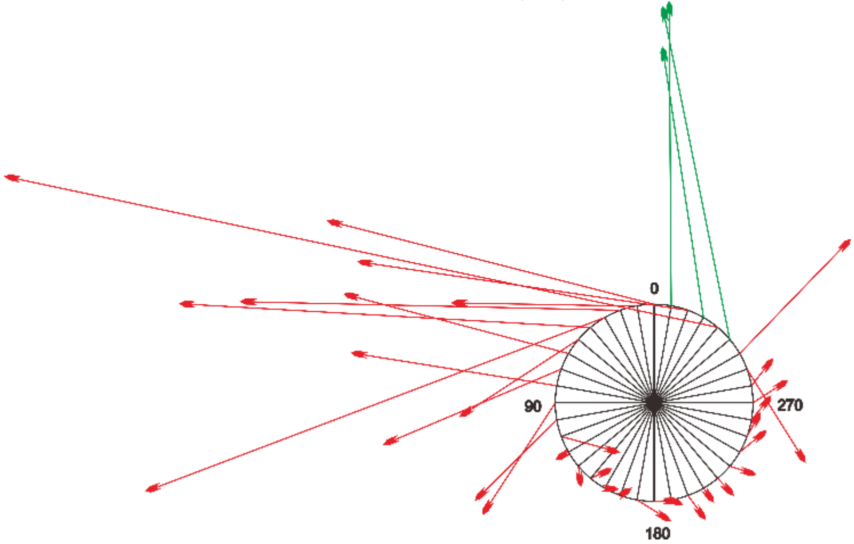

Figure 1. The pattern of intensity vector distribution of the midrange loudspeaker at frequency 3000 Hz.

Center point of the circle was the center of the sound source facing 0^o. The radius of the circle was 1 m measured from the center of the sound source. Based on the figure, the sound intensity distribution pattern tended to spread to the front and left side of the loudspeaker. At a frequency of 3000 Hz, sound intensity vector was greatest at the position 320^o with intensity of 14.640 V^2 leads to 118.440^o and the smallest in the position 150^o with intensity of 0.076 V^2 leads to 116.476°.

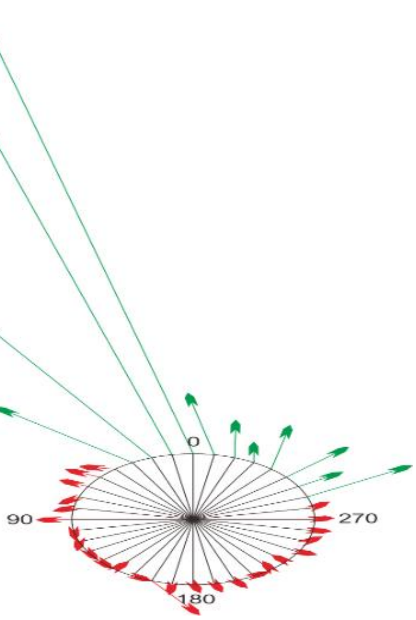

Figure 2. The pattern of intensity vector distribution of the midrange loudspeaker at frequency 6000 Hz.

From the analysis at frequency of 6000 Hz sound intensity vector value was dominant to the front of the loudspeaker. The greatest sound intensity was 119.819 V^2 at position 10^o and lead to 6.929° while the smallest 0.129 V^2 at position 180^o and lead to 26.564°.

CONCLUSION

At frequency of 3000 Hz distribution pattern of sound intensity vector tended to spread to the front and left side of the loudspeaker, while at frequency of 6000 Hz it more focused towards the front of the loudspeaker.

REFERENCES

Fahy, Frank. (1995). *Sound Intensity Second Edition.* London: Chapman & Hall.
Kinsler, L.E., Austin, R.F., Alan, B.C., & James, V.S. (2000). *Fundamental of Acoustics Fourth Edition.* New York: John Wiley & Sons, Inc.
Wikipedia. *Bunyi*. accessed from http://id.wikipedia.org/wiki/Bunyi. At December 20th, 2013.