THE EXPERIMENTAL RESULTS OF DOUBLE NEARFIELD ACOUSTIC HOLOGRAPHY METHOD FOR MIDDLE FREQUENCY SOUND SOURCES

Masao Nagamatsu

Hokkaido University of Science, Mechanical Engineering Department, Sapporo, Hokkaido, Japan
email: nagamatu@hus.ac.jp

I am now developing a new sound localization method, Double Nearfield Acoustic Holography (DNAH) method. The purpose of this proposing method is to improve the resolution of sound localization for low frequency sound sources. In this method, the measurement plane in the measurement of conventional Nearfield Acoustic Holography (NAH) method is doubled. By measuring the sound propagation information on doubled measurement plane, the preciseness of reconstructed images may be improved. In the past presentations, the theory of proposing DNAH method is explained. And the numerical simulation results and basic experiments are reported. These numerical simulations and experiments are carried out for the sound source(s) on and under 100Hz. In every case, the proposing DNAH method shows the better results than conventional NAH method. In this paper, the experimental result of sound localization for 1kHz and 500Hz sound source are reported. The resolution and preciseness of reconstructed images by proposing DNAH method and conventional NAH method are compared. As a result, In the 500 Hz results, the improvement of resolution is shown. In the 1kHz results, a little improvement of resolution is shown.
Keywords: Acoustic Holography, Sound localization

1. Introduction

There are some types of sound localization methods. These methods are used for detection of location of noise sources in developing mechanical products. There are some methods for sound localization. Recently many types of beam forming type measurement products are used in industry. And there is a more precise type localization method, Near Field Holography (NAH) method. However, this method is rarely used in industry because of heavy load in analysis computation.

I am now developing a new sound localization method, the Double Nearfield Acoustic Holography (DNAH) method [1]. This method is converted method of conventional NAH method. This method is developed to improve the performance of sound localization in low frequency. In former presentation, the experimental results of DNAH method with a small speaker are reported [2]. In these results, DNAH method shows the excellent performance as low frequency sound localization method.

In this presentation, the performance of DNAH method as middle frequency sound localization method is surveyed. The experiments are carried out with small speakers radiating 500Hz or 1kHz sinusoidal sound.

2. The theory of Double Nearfield Acoustic Holography (DNAH) method

In this chapter, the measurement setting and analysis theory of proposing DNAH method is explained. Because DNAH method is converted from conventional NAH method, the explanation of DNAH method is based on NAH method.

2.1 The measurement setting of DNAH method

The conventional NAH method needs measurement of sound field on one measurement plane. This measurement plane is set in the distance of the nearfield sound area from the sound sources, the surface of the machine. The figure 1 shows the draft of measurement of Conventional NAH method. On the measurement plane, the measurement points, which are the points that the sound pressure is actually measured, are located as the mesh pattern. The conventional Acoustic Holography method, the primitive method of acoustic holography, and which is also called as Microphone Array method, also uses single measurement plane configuration.

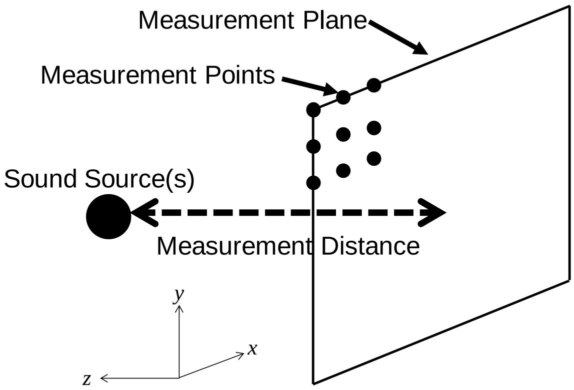


Figure 1: The measurement setting of conventional NAH method.

In the proposing DNAH method, the measurement plane is doubled. The figure 2 shows the draft of measurement of DNAH method. On the doubled measurement planes, the measurement points are located as mesh. The sound pressures are measured at measurement points on the front and rear measurement planes.

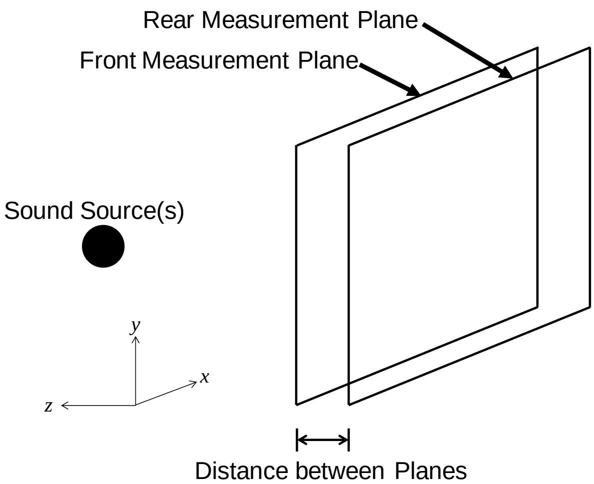


Figure 2: The measurement setting of proposing NAH method.

This style of measurement is possible only by using microphone traverse system, but is not possible by beam forming system.

2.2 Analysis of DNAH method

In the holographic method, the analysis calculation is required to acquire the visualized images. This calculation is called as the reconstruction calculation, and the visualized image is called as the reconstructed image. The figure 3 shows the computation steps of reconstruction calculation of the conventional NAH method.

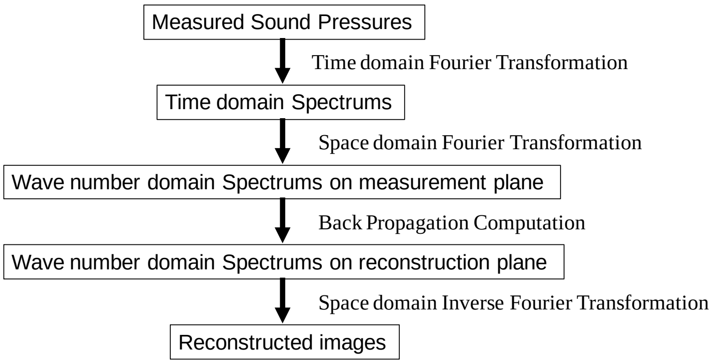


Figure 3: The measurement setting of proposing NAH method.

In the conventional NAH method, the measured sound pressures are divided into the spectra of each frequency by time domain Fourier transformation. The following steps of reconstruction are calculated for each spectrum. The next step is the 2 dimensional Fourier transform in the space domain. The result of this transform is 2 dimensional wave number domain spectra on the measurement plane. From these spectra, the 2 dimensional wave number domain spectra on reconstruction plane (i.e. the surface which is estimated as sound sources are exist) are computed by the back propagation computation. The formula of back propagation computation is as follows.

$$G(k_x, k_y, z) = e^{iz\sqrt{k^2 - k_x^2 - k_y^2}} \tag{1}$$

In this equation, z is distance between the measurement plane and reconstruction plane, and k is the wave number of sound of analyzing frequency. The kx and ky are the wave number frequency of each direction on the measurement plane. By multiplying G in the equation 1, the wave number domain spectra on the reconstruction plane is calculated. At last, the sound pressure distribution is calculated by the inverse 2 dimensional space domain inverse Fourier transformation. This distribution is the reconstructed image.

The equation 1 is the equation of the theoretical back propagation. In proposing DNAH method, the actual value of back propagation is computed from the datum difference between front and rear measurement planes. If the inner part of $\sqrt{k^2 - k_x^2 - k_y^2}$ in the equation 1 is a positive value, the absolute and argument of complex value G are as follows.

$$|G| = 1 \tag{2}$$

$$\arg(G) = z\sqrt{k^2 - k_x^2 - k_y^2} \tag{3}$$

From equation 2 and 3, it is found that the absolute of G is constant value, 1, and argument of G is proportional to the distance z. In the DNAH method, instead of equation 3, the equation 4 is used.

$$\arg(G) = z\{(\arg(P_f) - \arg(P_r))/d\} = \frac{z}{d}\{\arg(P_f) - \arg(P_r)\} \tag{4}$$

In this equation, d is the distance between the front and rear measurement planes, and Pf and Pr are the wave number domain spectrums of front and rear measurement planes. In the equation 3, the part of equation, $\sqrt{k^2 - k_x^2 - k_y^2}$ is logical shift rate of phase per z direction. In the DNAH method, the sound field is measured at the two points in z direction. Therefore the "actual" shift can be calculated. The equation 4 is the calculation of it. In this equation, the difference of phase of wave number domain spectrums between front and rear measurement planes is divided by the distance between the both planes.

If the inner part of $\sqrt{k^2 - k_x^2 - k_y^2}$ in the equation 1 is a negative value, the absolute and argument of complex value G are as follows.

$$|G| = e^{-z\sqrt{k_x^2 + k_y^2 - k^2}} \tag{5}$$

$$\arg(G) = 0 \tag{6}$$

In the proposing method, the equation 2 and 4 are used for back propagation analysis of the proposing DNAH method. In the figure 4, the computation steps of back propagation analysis in DNAH method is explained.

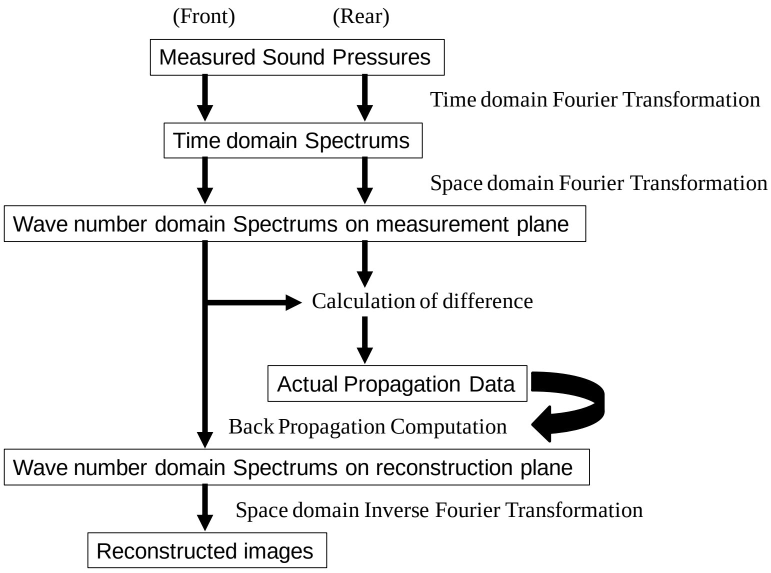


Figure 4: The analysis steps in proposing DNAH method.

3. The experimental setting and experimental equipments

In this paper, the performance of DNAH method as sound localization method in middle frequency is discussed by some experiments. The experiments are carried out at 1kHz and 500Hz. The experiments are executed in the laboratory environment. The sound source is a small speaker. The diameter of the speaker is 8cm. The measurement method is scanning method. Two microphones which move vertically and horizontally are used as scanning microphones. In reconstruction computation of conventional NAH method, only the datum measured by front scanning microphone is used. In reconstruction of proposing DNAH method, both of front and rear datum are used. Though the sound of experiments is constant, the reference signal is input from the signal generator which makes the signal for the speaker. The figure 5 is a photo of measurement equipments of experimentations.

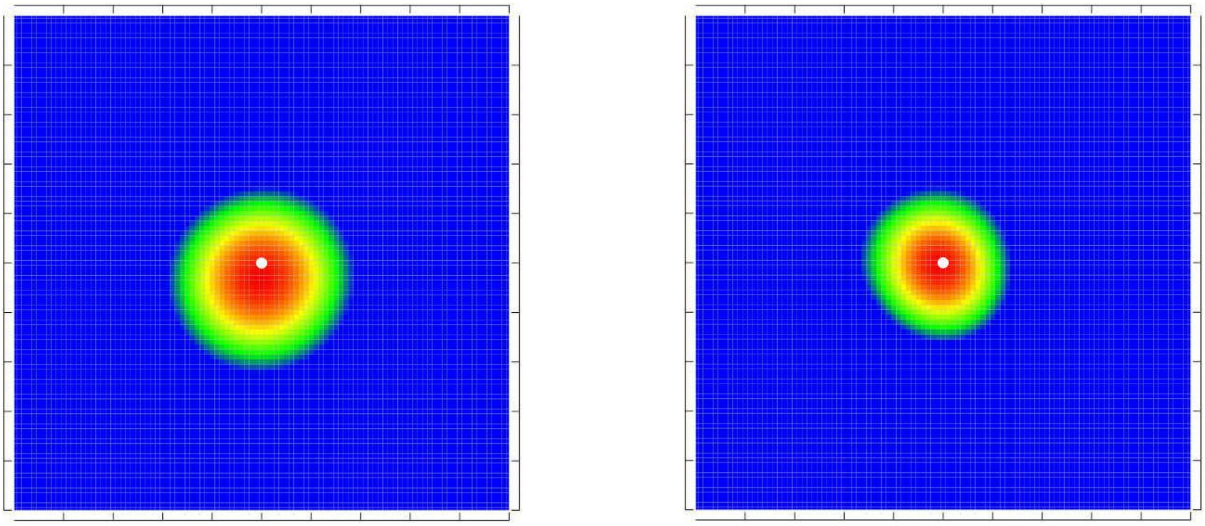
The size of scanning area and reconstruction area is horizontally (x-direction) 1m by vertically (y-direction) 1m. The measurement points are set as mesh pattern with 0.1m pitch horizontally and vertically on front and rear measurement plane. The distance between front and rear measurement planes is 0.15m. The reconstructed sound pressure distribution is described as colour contour images. In the images, the level is depicted red, yellow, green and blue colour, from the top level in each image, and the difference of level between each colour is 2dB. The white dot(s) in the image is the location of centre of speaker(s).

Figure 5: The measurement equipments.

4. The experimental results

4.1 The experimental results for 500Hz sound

In this section, the experimental results at 500Hz are explained. The figure 6 is the experimental results with a sound source located at centre of measurement area.

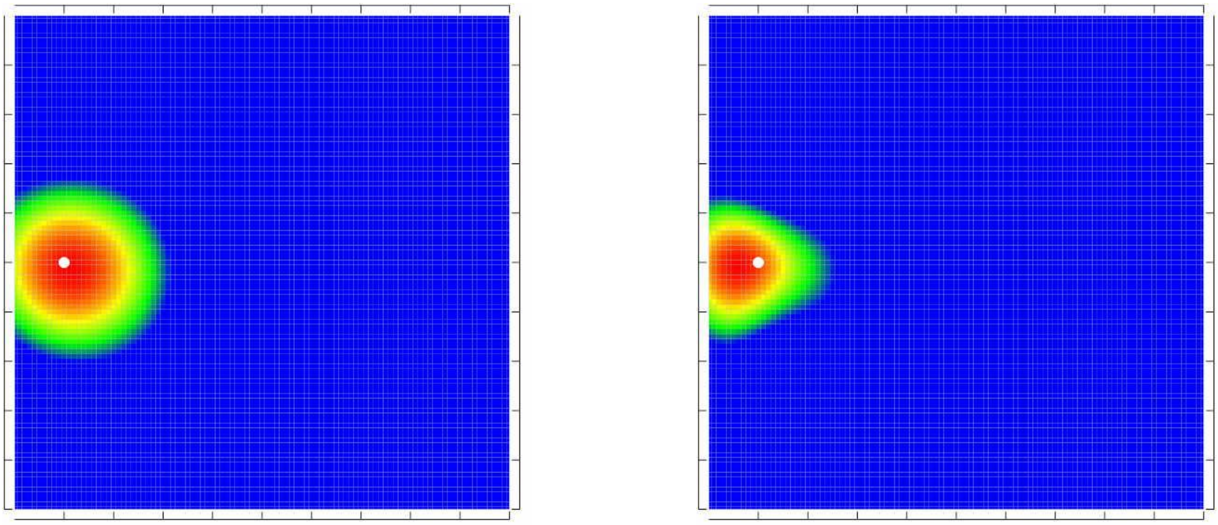


(NAH) (DNAH)

Figure 6: The experimental results. A sound source is located in centre.

In this experimental result, the image by proposing DNAH method shows shrunk image compared with the image by conventional NAH method.

The figure 7 is the experimental results with a sound source located at side of measurement area.

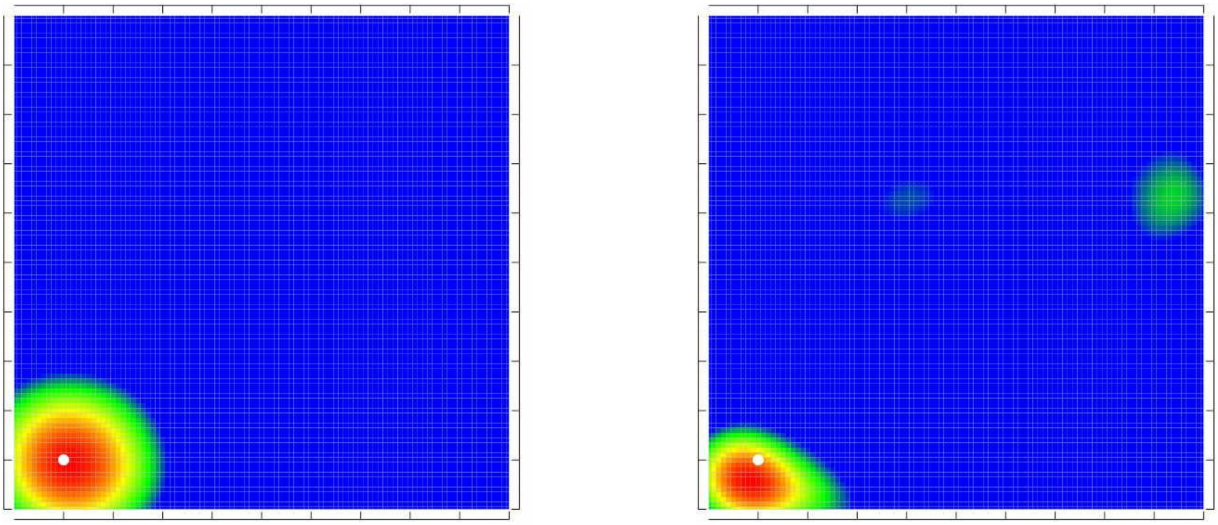


(NAH) (DNAH)

Figure 7: The experimental results. A sound source is located in side.

In this experimental result, the image by proposing DNAH method also shows shrunk image compared with the image by conventional NAH method.

The figure 8 is the experimental results with a sound source located at corner of measurement area.



(NAH) (DNAH)

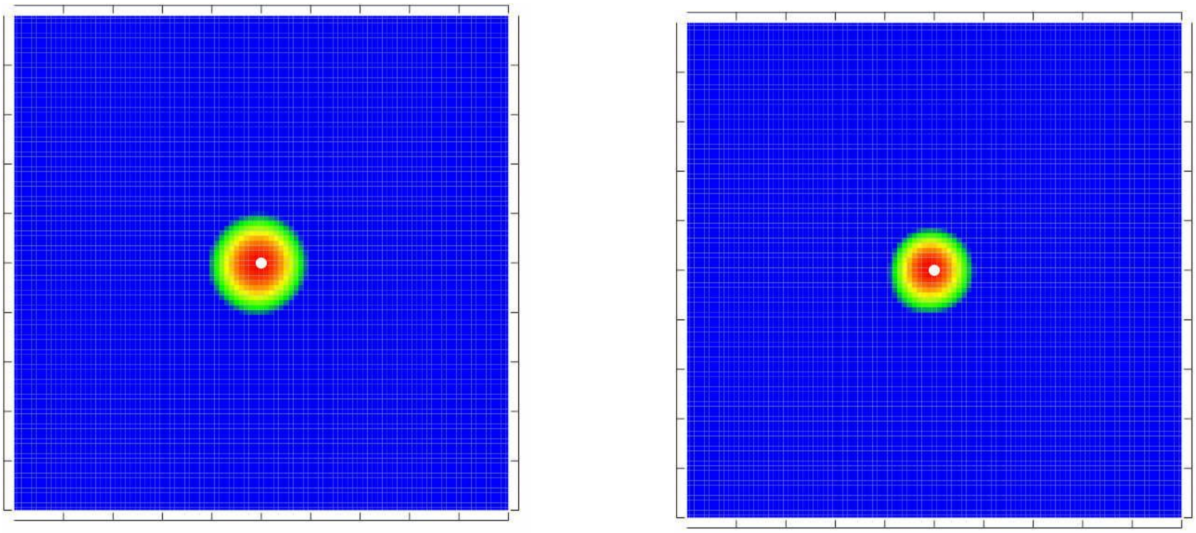
Figure 8: The experimental results. A sound source is located in corner.

In this experimental result, the image by proposing DNAH method also shows shrunk image compared with the image by conventional NAH method. However, the preciseness about the position of the sound source becomes worse. Because the image of the sound source is shrunk, the ability to recognize the multiple sound sources as individual, may be improved. However, the preciseness of location is not good in proposing DNAH method.

As a whole, the proposing DNAH method shows better results compared with conventional NAH method.

4.2 The experimental results for 1kHz sound

In this section, the experimental results at 1kHz are explained. The figure 9 is the experimental results with a sound source located in centre.

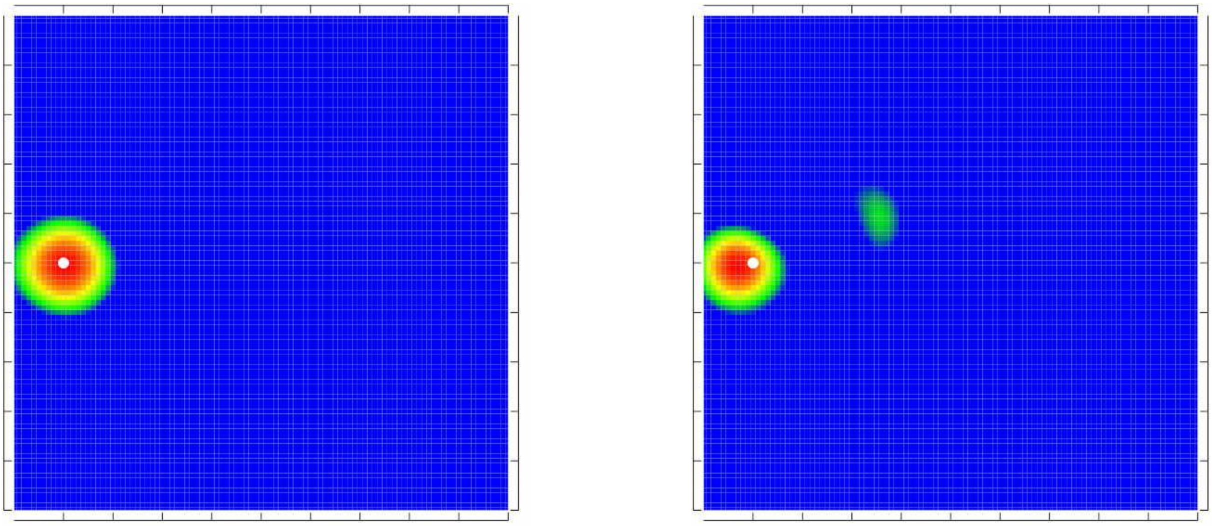


(NAH) (DNAH)

Figure 9: The experimental results. A sound source is located in centre.

In this experimental result, the image by proposing DNAH method shows a little shrunk image compared with the image by conventional NAH method.

The figure 10 is the experimental results with a sound source located at side of measurement area.

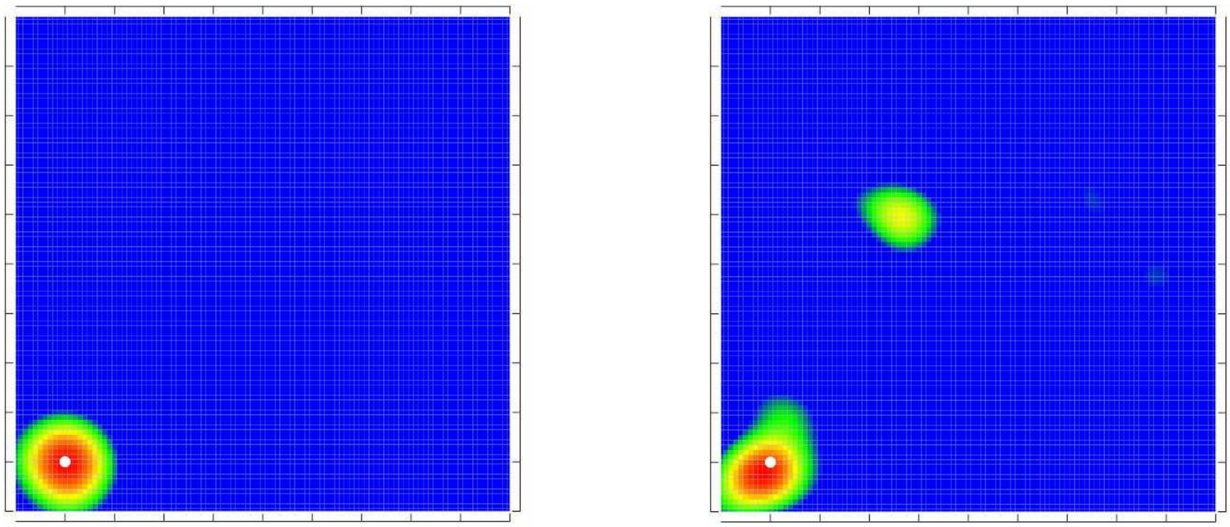


(NAH) (DNAH)

Figure 10: The experimental results. A sound source is located in side.

In this experimental result, the image by proposing DNAH method also shows a little shrunk image compared with the image by conventional NAH method. However, the preciseness of sound source location becomes a little worse.

The figure 11 is the experimental results with a sound source located at corner of measurement area.



(NAH) (DNAH)

Figure 11: The experimental results. A sound source is located in corner.

In the image by proposing DNAH method, the subsidiary image is shown. The main image largeness in both results is almost same.

As a whole, the proposing DNAH method and conventional NAH method shows almost same images at 1kHz.

I did experiments at higher frequency than 1kHz. However, the difference between the results of proposing DNAH method and the results of conventional NAH method, is small.

5. Conclusion

In this paper, the experimental results of proposing DNAH method and conventional NAH method are explained. In 500Hz, the DNAH method shows better results than NAH method. however, in 1kHz, the results by DNAH method is almost same with the results by NAH method.

REFERENCES

1 Nagamatsu, M., Conversion of Nearfield Acoustic Holography Method for Low Frequency Localization, *Proceedings of the 22nd International Congress on Sound and Vibration*, Florence, Italy, 12–16 July, (2015).

2 Nagamatsu, M., Basic Experiments of Double Nearfield Acoustic Holography Method *Proceedings of the 23rd International Congress on Sound and Vibration*, Athens, Greece, 10–14 July, (2016).