EXPERIMENTAL RESEARCH ON VIBRATING PLATE AND ITS RADIATION FIELD USING NEARFIELD ACOUSTIC HOLOGRAPHY

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ABSTRACT This paper presents the nearfield acoustic holography (NAH) imaging system for airborne sound constructed in our own laboratory. The effects of different kinds of noise and the filter function's form in wave number space for reconstructions are analysed emphatically. Using the system we have measured the vibrating mode and the radiated field of a simulative " Chime Stone " made by metal, and gotten interesting results. These results indicate that NAH can be used to research the mechanism of sound production and evalution of musical quality for Chime Stone as an effective means.

1. INTRODUCTION

Although the theoretical analysis of the imaging method and characteristics of the Nearfield Acoustical Holography (NAH) was systematically expounded in many paper[1] [2], the experimental research needs to be enhanced as compared with the theoretical analysis. In order to make NAH experiment we have set up a NAH system for airborne sound radiation research. As has been pointed out by several authors, when we measure the hologram data using any practical NAH system, the measuring errors of all kinds will be introduced into the data, such as environment noise, ununiformity among the elements of the receiving array, electronic noise in the data acquisition hardware, finite size receiving aperture, larger separation between the samples and the computer's limited numerical accuacy. It is quite evident that these noise will be also introduced into the wave number space or called K-space follow the hologram data transformation. In the process of the reconstruction compounding these error is the exponential growth associated with back propagation due to the Green's Function becomes an exponential amplifier here. This cause leads to the results that the resolution is reduced, and the inconsistancy of reconstruction results is increased. For this reson, it is necesscary that the errors should be reduced to the full, and the filter function in the K-space should be used.

2. EXPERIMENTAL SYSTEM

The NAH experimental system we designed and made is shown in Fig. 1.

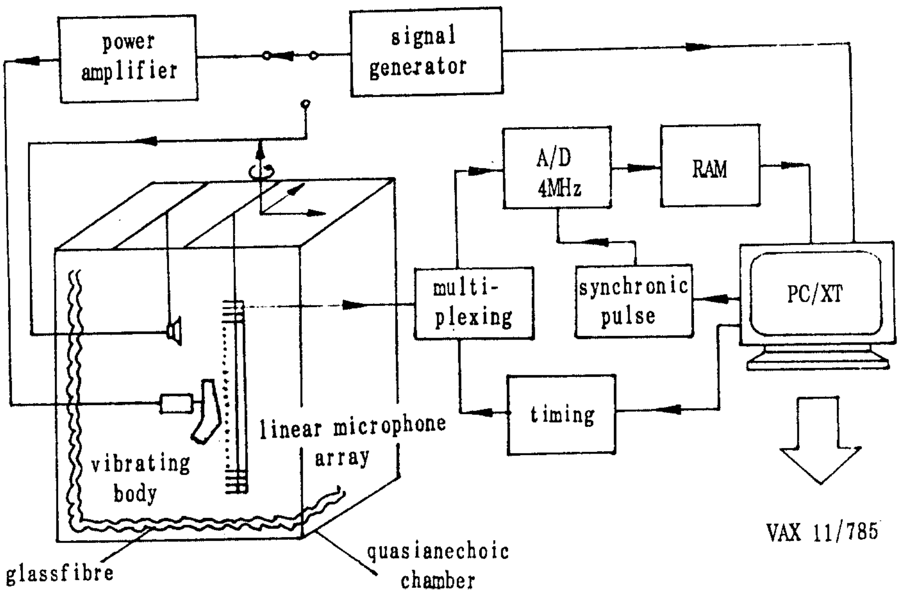


Fig. 1 A block diagram of NAH system for airborne sound

To design a NAH system with a large dynamic range, one should adopt a vibrating body working in a wide linear response. In our experiment, the vibration frequency is below 1KHz, i.e. the wavelength in the air $\lambda \geq 0.34$m. The dimension of the vibrating body $D_0 \leq 0.5$m. We made a 32-element linear array of electret microphone, where the radii of microphones a=0.005m, the length of the array L=2.08m, the radius of the steel pipe used to install the microphones a'=0.009m, the distance between two elements is d'=0.065m. The parameters given above satisfy the following needs of NAH experiments: $L \geq 3D_0$, a and $a' \ll D_0$, $d' \ll D_0 < \lambda$. The distance between the vibrating body and the receiving array is taken among d=0.02~0.07m to ensure to receive the evanescent wave components effectively.

The tested vibrating body and receiving array are installed on two scanning vehicles seperatly, which both can scan in three dimensions and rotate along the azimuthal angle. In the case of normal experiments, we make the vibrating body or array scan in level direction step by step, and obtain 32×32 hologram data configuration, covering an aperture of L×L. For high-frequency vibration, we can reduce the sampling separation and increase the sampling points in order to get 64×64 or 128×128 hologram data. Similarly, for small-scale vibrating body, we can reduce the aperture, such as L/2×L/2, and get 32×32 or 64×64 hologram data.

The experimental space is a original sound-absorbing tank of $6\times5\times4m^3$. For eliminating the disturbance from wall reflection and environment noise, we install the glass fibre lining on the walls and ceiling of the tank. The thickness of the lining is 0.4m (about $\lambda/4$).

The multiplexing system can be used to acquire the time series signals of 32-element linear array not only in the circulatory sampling way but also in the sequental sampling way. The time sequence signals passed A/D converter and stored in a high-speed buffer memory RAM of 8K bytes. After pre-processed (i.e. the FFT at the frequency of sound) by the microcomputer PC/XT, the data are transferred to VAX 11/785 to reconstruct.

On the basis of mathematical formulas shown in our work[1], we have compiled complete operational program, in which a new filtering function we name it " least squares method filtering function with restraints " is applied to the K-space processing. The form of the new filtering function is as follows[1]

$$H_d(K_x, K_y) = \begin{cases} \dfrac{1}{1+(\varepsilon/E)^2(K_x^2+K_y^2)}, & K_x^2+K_y^2 \leq K^2, \\ \dfrac{1}{1+(\varepsilon/E)^2(K_x^2+K_y^2)\exp(2d\sqrt{K_x^2+K_y^2-K^2})}, & K_x^2+K_y^2 > K^2 \end{cases}$$

Where ε/E indicates signal-noise ratio of measuring data.

3. RESULTS AND DISCUSSION

Using our system we have measured the vibrating mode and the radiated field for a single loudspeaker source, double-loudspeaker source and a unbaffled disc. The results concerning this research will be puglished on the CHINESE JOURNAL OF ACOUSTICS this year.

For the sake of researching the complex mode vibrating plate and its radiation field, we designed a simulator of the Chinese ancient musical instrument " Chime Stone " made by steel plate with the thickness of 0.002m. The geometry of the simulative "Chime Stone" is shown in Fig. 2

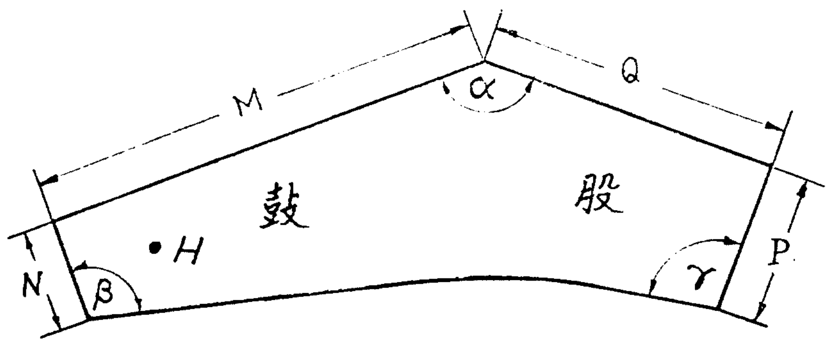
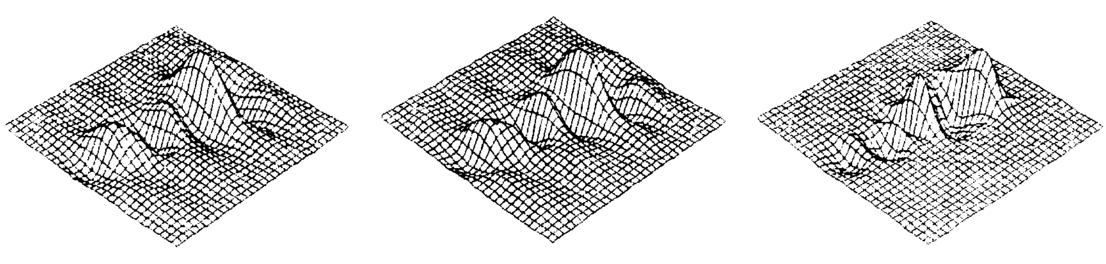


Fig. 2 The geometry of the simulative "Chime Stone"
P: Q: M: N=1: 2: 3: 2/3 P=120mm H--beating point
$\alpha=135^o$ $\beta=103^o$ $\gamma=100^o$

The output signal of the generator was sent to a power amplifier to drive a vibration exciter (B&K Type 4809). The axis of the exciter is jointed with the position for beating (it is named "鼓" which means drum), and make it to vibrate forcedly. Regulating frequency of the generator, the simulator can vibrate with several modes.

Fig. 3 is the reconstructed results of the vibrating mode for simulator driven at f=154 Hz, where the aperture is $L/2\times L/2$, sampling data are



a. pressure b. velocity c. intensity
Fig. 3 The reconstructed vibrating mode at 154 Hz

32×32, the measurement distance d=0.06m and signal-noise ratio ε/E= 0.005. Fig. 4 shows the reconstructed spatial vector intensity field in the directional plane contain acoustical axis and scanning line of the element number 15. Fig. 5 gives the reconstructed mode at 367 Hz. Fig. 6 shows the corresponding intensity field.

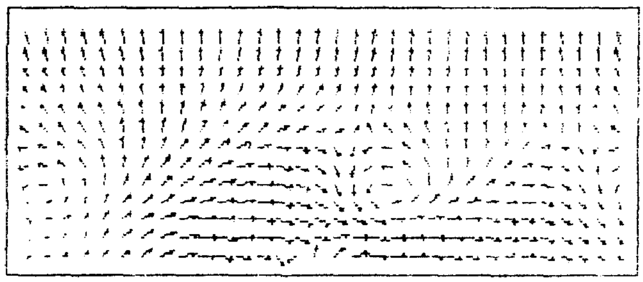
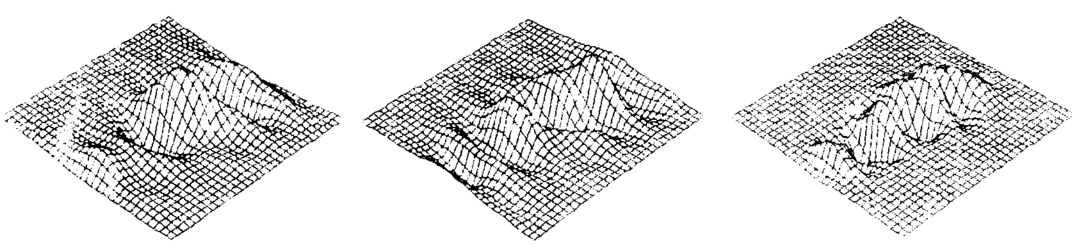


Fig. 4 The reconstructed spatial vector intensity field at 154 Hz



a. pressure b. velocity c. intensity

Fig. 5 The reconstructed vibrating mode at 367 Hz

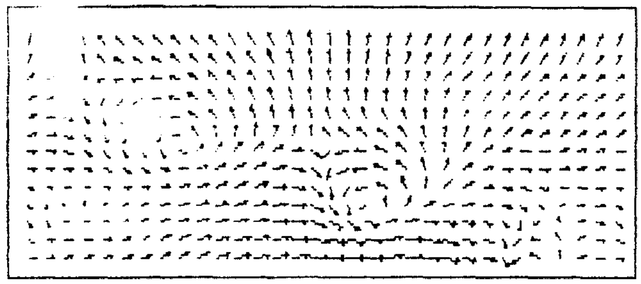


Fig. 6 The reconstructed spatial vector intensity field at 367 Hz

On the basis of above experimental research, the following preliminary conclusion can be made. These are:

1) The simulator of chime stone has more complex vibrating mode, and is quite different from the rectangular plate. The vibrating modes of the simulator depend on its unique geometrical form and sizes.

2) The high frequency mode of the simulator is complex more than the low frequency mode. The numbers of "circulating energy flow" in the former's spatial vector intonsity field are more than the latter's.

3) Besides 154 HZ, 367 Hz there are some other resonace frequencys in the spectra of the simulator. They are on the whole harmonic in the musical sound.

In a word, these phenomenons remain to be further researched, but the results of the experimental research has indicated that the NAH is a powerful tool that can be used for the research of the relation between the mode of vibration and its radiation field.

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